Leonard de Vries

The Third Book of Experiments

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The Third Book of Experiments

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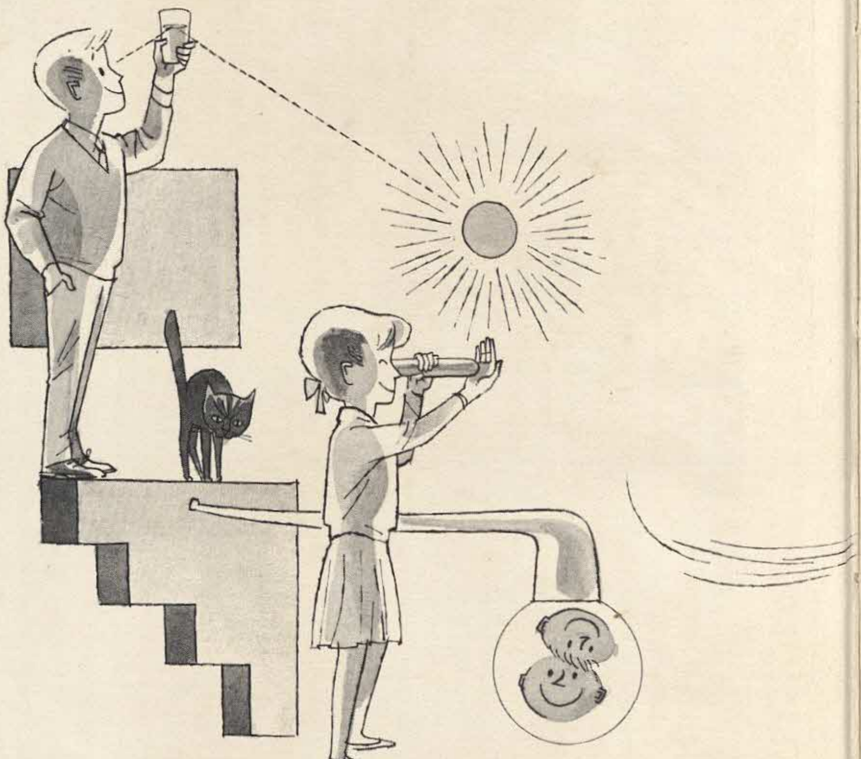

Leonard de Vries

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Book of Experiments

Illustrated by Joost van de Woestijne

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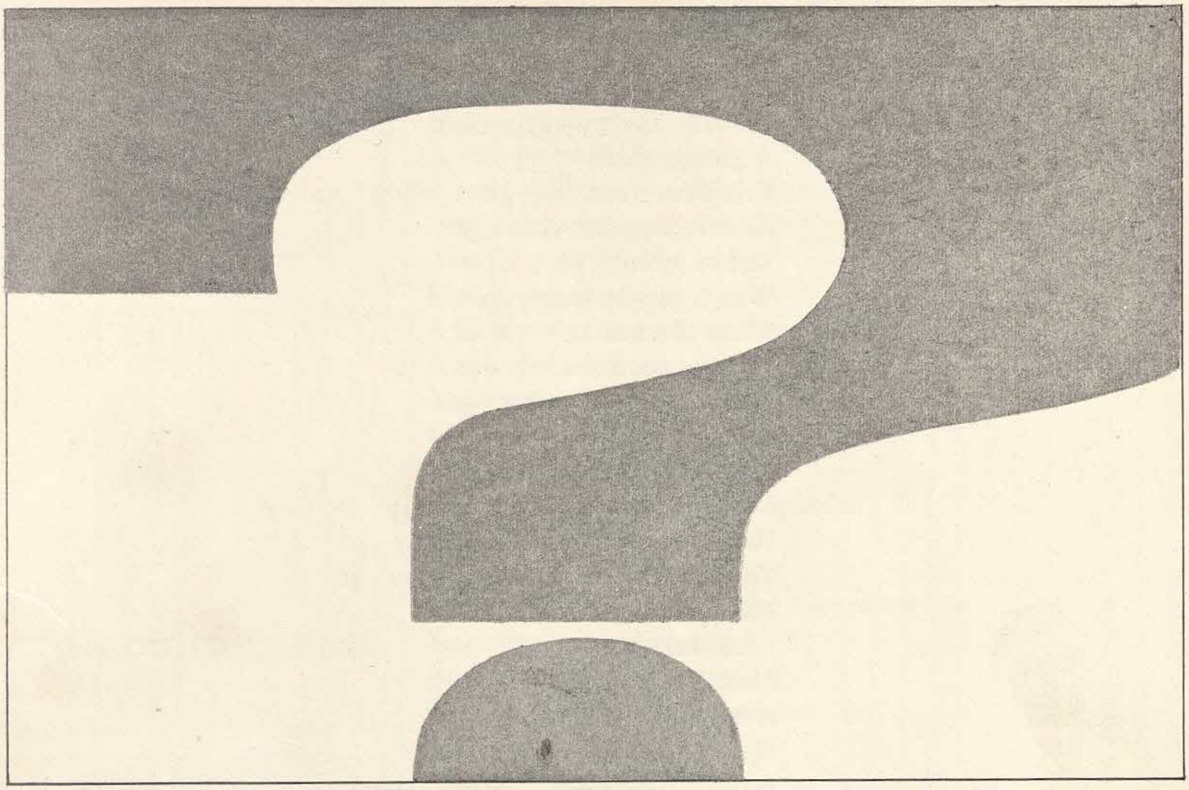

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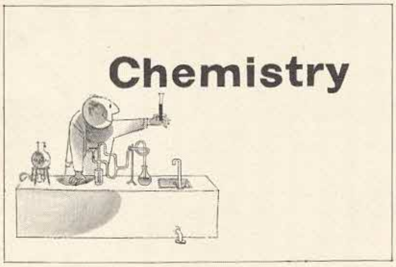

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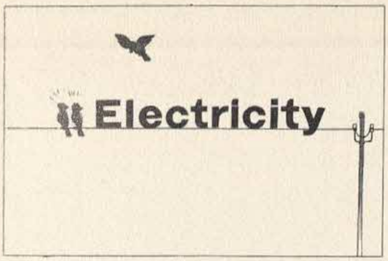

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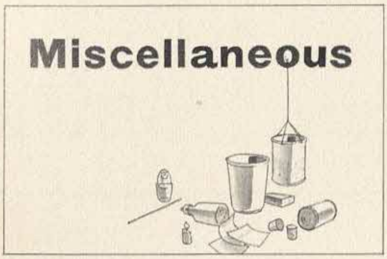

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Combustion

Between two fires

Fire! When we hear this cry, we jump to the conclusion that something is on fire. Or possibly we think of guns and cannons. But why should we immediately think of fire in its most unpleasant forms? Fire has many good properties—more than you'd think! To start with, fire gives us warmth in winter, tasty cooked food, all sorts of comfortable and comforting things. . . .

Now don't say, 'Yes, but *we* heat our water and do our cooking by electricity!', for most electricity is generated by fire. So it's also thanks to fire that we have electric household appliances, radio, record players, television . . . and many other things besides.

And this is only the beginning! I wonder if you are now looking round the room in surprise trying to find more things which are connected in some way with fire. What can you see? Come on, list them. The windows, wallpaper and paintwork, furniture, curtains and other sorts of textiles, various objects such as a clock, pictures or paintings, a pen, bowls or vases, books . . . mention everything you see. Perhaps you'll have a list of a hundred different things!

Fire—the creator

Well, without seeing your room I still dare to claim that practically everything, with the exception of potted plants and pets, has come into existence thanks to . . . FIRE!

Check on it yourself. There are the window panes and other things made of glass. You realise that glass is made by melting in great heat a mixture of sand, soda, lime and often other materials. Is your clock made of metal? Anyway, there's metal inside it. And I'm quite sure there's more metal in your room. You'll know what I'm driving at: most metals are smelted from ores at very high temperatures. Iron and steel are obtained in the fiery blaze of blast furnaces. Everything made of plastic is also obtained from raw materials submitted to high temperature and pressure. Therefore with no fire there would be no plastics.

Wallpaper, books, newspapers, periodicals . . . Paper is produced by boiling finely chopped wood in chemical baths. The substance produced in this way is sprayed over revolving brass mesh. The paper from which you are now reading was made by means of suction, pressing, heating and therefore drying. It's also thanks to fire that the printing ink on this page was made. The main constituent of black printing ink happens to be the soot which is produced by the partial burning of petroleum.

All china and earthenware has been 'fired' in a hot oven. And those who live in a brick house should remember that the transformation of lumps of clay into bricks is achieved in a well-stoked brick kiln. But to come back to our room, what else can we see? A great deal of woodwork, sawn with an electric saw and stained or painted. From whatever raw materials this stain and paint are made, it is certain that they came out of hot boilers. The same goes for varnish and most sorts of glue. And what about the plaster on the walls and ceiling? Have you ever heard of lime kilns . . . ?

We could go on like this for a long time, for honestly, we wouldn't come across very much in the house which has not in some way or other come in contact with heat, which means fire. All colouring matter, the different sorts of textiles, rubber and leather and everything you wear from clothes to buttons, zips and watch—all these would never have existed without fire!

Did you hear that car pass? A car like that is propelled by the power of exploding petrol vapour or, in other words, fire! And then there's that mighty jet liner high up in the air. In it there are more than a hundred passengers who are going to cross the ocean at a speed of five hundred miles an hour and who are being propelled by flames, very carefully controlled flames, but still full of roaring strength.

In fact, if we think about the origin of things around us, we come up against fire nearly every time, and this is true not merely of man-made things. Just think of the gigantic mountains of granite or basalt. These giants, thousands of feet high, have crystallized from a white-hot mass. . . .

Earth's fiery centre

Look . . . look back . . . look back into the past . . . about three thousand million years ago. Look at that inky-black, star-studded sky, in which a globe of red-hot, viscous liquid matter is revolving in shining splendour. Watch it as if you were looking at a film being run off too quickly; and as the years spin past, see how that globe radiates its heat into space, and through the loss of this heat becomes cooler. Its outside sets into a tough,

malleable crust of lava, which solidifies into hard rock. The vapour also cools off and condenses into thick clouds which send heavy downpours of rain on to the rock, so that the deepest basins are filled and become seas and oceans. That red-hot globe is our earth!

In the same way as a dried-up apple develops a wrinkled skin, so the earth's crust, which is slightly too big, has crumpled into folds around the red-hot and still fluid interior, which has shrunk through having cooled. The pressure inside is so great that the magma, the fluid rock, breaks through the thinnest parts of the earth's crust and forces its way out in volcanic eruptions —spitting fire, smoke and flames. It's as if all the fury of hell had broken loose! The internal pressures transform the earth's surface. Thus colossal forces push and bend, twist and mould the rock. Islands rise up out of the oceans; elsewhere wide areas of land sink into the depths and disappear under the waves, and in yet other parts of the sea high mountain ridges rise up. Thick new layers of earth spread over the existing surface, obliterating whole landscapes. In other places the crust of stone bursts open, forming deep cracks into which the waters of the ocean pour and turn explosively into steam when they come in contact with the fierce heat of the magma.

Hundreds of craters belch lava and rocks over a vast area, the earth's surface rolls and trembles with the thunder of volcanic eruptions, and this blends with the roar of storms and the crackle of lightning. Clouds of ash sometimes obscure the sun, volcanic eruptions throw a blood-red glow over this wild play of the elements. Cold and heat, rain and drought, creation and destruction, rising and sinking, follow each other in turn. The earth is full of movement . . . but without life.

A film of the earth's story

Life? If there were an hour-long film showing the development of the earth from its beginnings up to today, then half an hour would pass before the first living thing came into existence. First there is one-celled life in water from which evolve, after millions of years, primitive plants and animals. Then our film runs on and we see the first fish, then grass, moss and fern covering the most fertile stretches of land. Where the climate is hot and damp we see suffocatingly thick jungles of tree fern growing. The leaves collect solar energy. Later—*very* much later—after these leaves have rotted and been pressed together, seams of coal are formed. Something rather similar happens to the plankton and other micro-organisms from the sea—petroleum comes from these. In this way a gigantic supply of fuel is made. . . .

Some of the fish develop lungs; these turn into amphibians and later into reptiles. And then, when there's only five minutes left of our one-hour film—oh! how terrifying! The most fantastically shaped animals appear on earth, giant reptiles of really vast dimensions, some of them fifty feet long and as tall as houses, weighing tons: colossal creatures with cumbrous bodies and long necks, with scales or horns and sharp fangs.

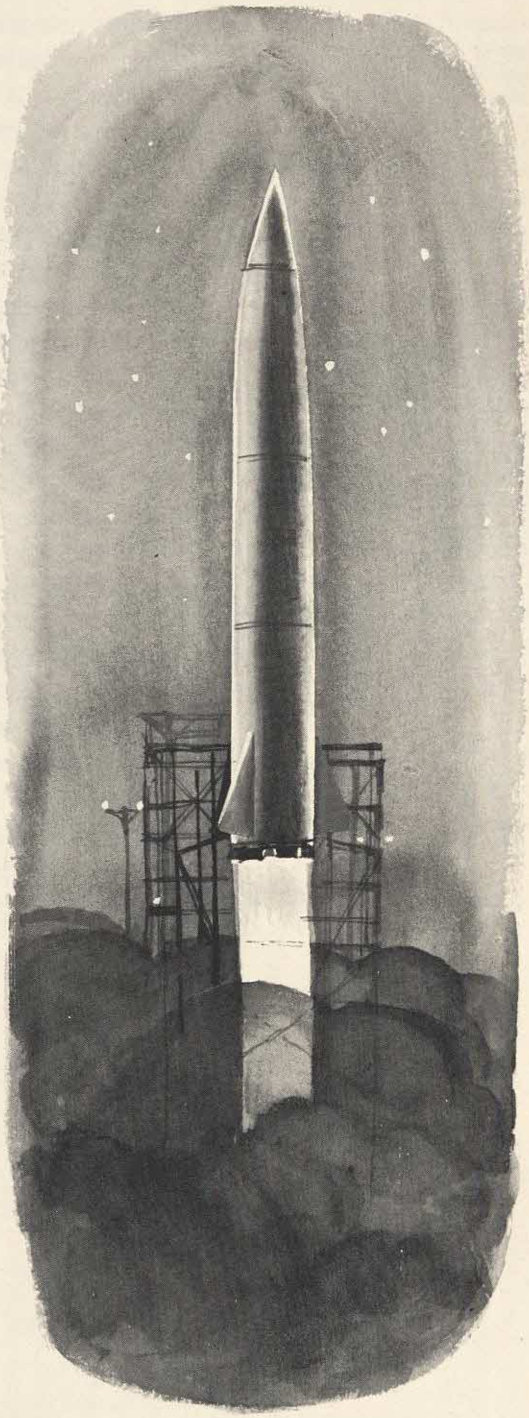
One picture after another flashes on the screen. The gigantic monsters are replaced by the much smaller and more intelligent mammals. Ice ages and warmer periods follow each other, a funny little ape-like creature appears as a fore-runner of someone whose appearance on earth we are expectantly awaiting. But in that we're disappointed, because suddenly the film ends and it is only in the very last second that we catch a fleeting glimpse of the being who is to dominate the whole earth: man.

So now you see that if the three thousand million years' history of the planet earth is condensed into one hour, then the one or possibly two million years of man's existence last for only a second or two. To the great annoyance of the historians, man only began to write down some of his thoughts and experiences about six thousand years ago. Of the people who lived before that—in prehistoric times—we know only what we can deduce from excavated remains and tools and from cave drawings. Thanks to the fortunate fact that in those times the ground was used as a dustbin and there was no question of municipal burning of refuse, the archeologists have been able to piece together quite a lot of knowledge about prehistoric man. Amongst other things, we know that he was exposed to big climatic changes. There were the ice ages, when glaciers like walls of ice pushed remorselessly southward, crushing and burying everything in their way, and it became colder and colder.

Fire—the friend of man

But in the end it was those very glacial periods which, instead of weakening or destroying man, in fact made him stronger. For the grim struggle with Nature forced man to use his brains and to improve his equipment. It was now that he made friends with fire, and used it to his advantage. In order to get a fire going, he no longer had to depend on forest fires caused by lightning or spontaneous combustion: he was able to make fire himself by hitting or rubbing flint to make sparks. Fire became an important ally in the battle of existence. It protected him from the cold and against wild animals; he could prepare and conserve food with it, and it provided light in the darkness. Of all the inventions of man, the art of making fire was probably the most important!

For it is to fire—and this will be clear to everyone by now—that we owe the whole of our modern, industrial society. Space travel too, which will enable man to leave the earth for a time to explore the moon and a few planets, depends on the use of fire—the fire of the rockets. Past, present, future: fire was, is, will be an indispensable part of the life of man.



A complete laboratory in a candle

1 candle
Matches
1 narrow glass tube with tapered nozzle
1 funnel
1 piece of metal gauze
Aluminium foil
Snow or chopped ice
1 piece of white card

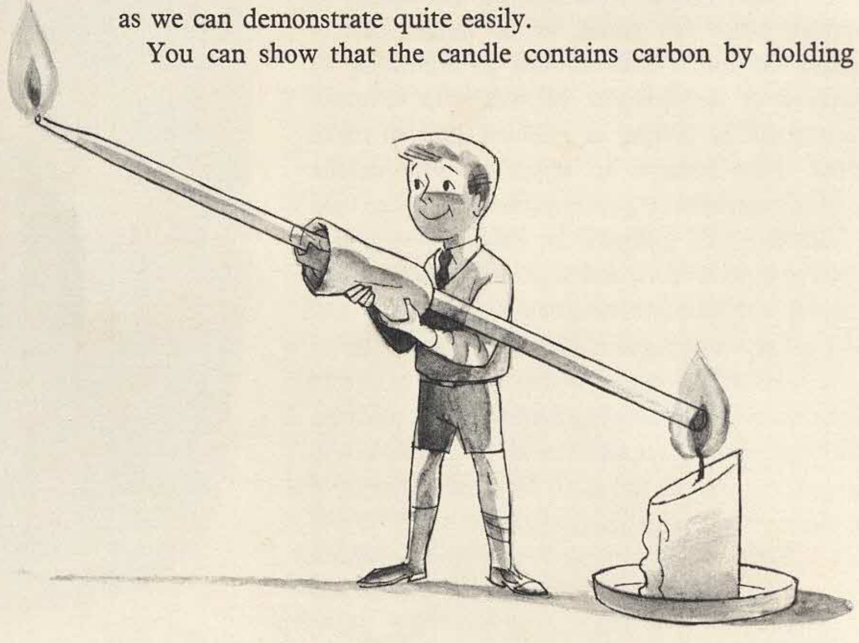
Just over a hundred years ago the well-known scientist Michael Faraday gave a series of lectures on a single subject, *The Chemical History of a Candle*. By his demonstrations, which were meant as an introduction to physics and chemistry, Faraday showed that the burning of a candle flame combined these two branches of science in the most extraordinary manner.

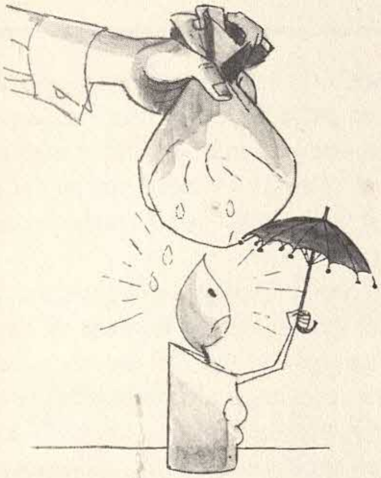
When you light a candle you begin by turning a solid into a liquid which, in its turn, changes into a gas which can burn. By capillary action (see experiment *Capillarity is irresistible* on page 97) the liquid wax rises up the wick. Through the chemical reactions during combustion, energy is released in the form of light and heat.

There are two ways in which you can show that a candle flame consists of a burning vapour. Blow the burning flame out, and immediately hold a lighted match an inch or two above the wick. The inflammable vapour catches fire and the candle lights again. You can also put into the flame a narrow glass tube with a tapered nozzle. Hold a lighted match beside the nozzle and the inflammable vapour which comes out of the tube will catch fire.

Burning, or combustion, is simply the chemical combination of a substance with oxygen. Candle-wax is a complex chemical compound of carbon and hydrogen. During combustion the carbon unites with oxygen to produce carbon monoxide and carbon dioxide, and the hydrogen unites with oxygen to produce water, as we can demonstrate quite easily.

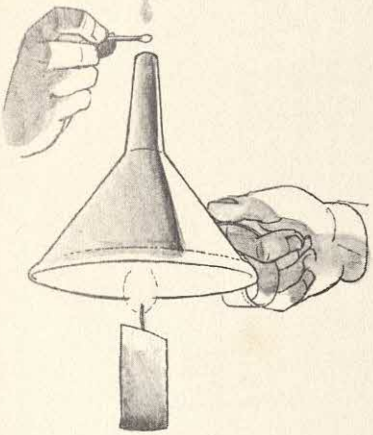
You can show that the candle contains carbon by holding a





cold saucer or a piece of metal gauze in the flame. Soot is deposited on it, and soot is carbon. Make a little bag from aluminium foil and put into it some snow or chopped ice mixed with a little salt. If you hold it above the flame, the water vapour given off by the burning hydrogen cools and condenses, forming little drops on the outside of the ice-cold bag. A simpler but much less effective experiment is to hold a cold tumbler upside down above the flame and tiny drops of water will collect inside.

You can show the presence of carbon dioxide by holding a funnel upside down over the flame. Bring a burning match to the outlet of the funnel and the rising carbon dioxide puts it out. You can also hold a piece of gauze over the flame. Bring a burning match up, over the gauze, and it goes out immediately, extinguished by the carbon dioxide. Hold the gauze a little lower down, actually in the flame, and you will see that the flame does not come above the gauze. You will notice, too, that the centre of the flame is dark. This non-luminous centre consists of gas. Around it lies a mantle of glowing particles of carbon which give out the actual light. They burn to carbon monoxide and then to carbon dioxide. This mantle is much hotter than the centre, a fact which you can demonstrate by holding a piece of white card quite level in the flame. A brown ring is scorched on the card, the diameter of the mantle, while the centre remains unscorched.



If you stand a burning candle in the sun and let the shadow fall on a sheet of white paper you will notice that the most luminous part of the flame produces the darkest shadow, while the core of gas lets the light through best.

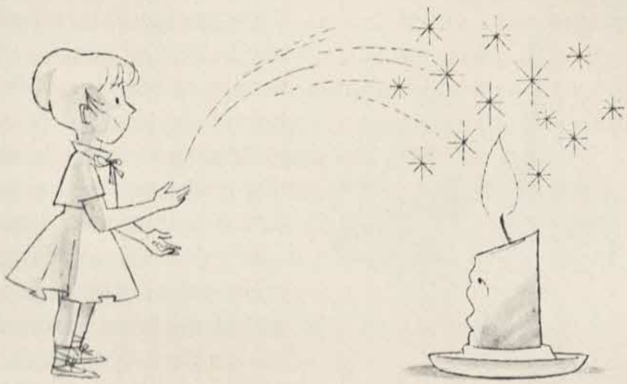
So you see how a single candle contains a whole laboratory!

Miniature fireworks

1 empty pepperpot
1 piece of rosin
1 lighted candle
1 piece of cloth
1 hammer

You can make a beautiful, but perfectly safe, miniature firework with some powdered rosin. Try to get a piece of rosin, perhaps from a friend who plays the violin—or you may be able to take a piece from a fir tree. Put the piece of rosin—it need not be very big—into the cloth and hammer it well until it is all crushed to a fine powder, the finer the powder the better.

Transfer the powdered rosin to the pepperpot, light the candle and sprinkle some of the powder in the flame. Because of the fineness of the rosin and the abundant supply of the essential oxygen, each little grain burns in a fraction of a second, making a bright spark. All the little grains together make hundreds of thousands of these sparks and so produce quite an impressive firework.



Can steel burn?

1 metal wire
Some steel wool
1 piece of paper
1 candle

Anyone who thinks that metals cannot burn is sadly mistaken! Just think of magnesium, the metal used in flashbulbs, which gives out an extremely bright light when it burns. Steel and iron too will burn and with a bit of steel wool we can make delightful sparklers.

From a wad of the wool tease a little bit out and attach it to a piece of wire. Round the other end of the wire wrap a bit of rag or some paper so that you can still hold it when it gets hot.

Now hold the steel wool over a flame, for example a candle flame, and you will see pretty sparks jumping out of the wool. There is nothing to be afraid of—these sparks are not dangerous.

What are these white-hot sparks? Burning steel! It combines in the flame with the oxygen of the air to form iron oxide.

Where does the soot come from?

1 old saucer
1 candle
1 drinking straw
1 pin

If you hold a saucer in a candle flame it gets covered with black stuff—soot. What is soot? Incompletely burned fuel. But soot is carbon, and carbon is burnable. If soot is produced, that is a sign that combustion is not taking place completely. Soot formation indicates a waste of fuel!

By making a candle flame hotter we can show that soot can still be burned. To do this stop up one end of a drinking straw with a bit of clay, a ball of wet paper or a little piece of cork. Near the closed end make a hole with the pin. Damp that part of the straw so as to prevent it from catching fire. Now hold the straw so that when you blow down it through the flame it is directed on to a spot of soot. You have made a blowpipe. By blowing like this you make a strong, pointed flame which plays on the soot. You will see the saucer becoming quite clean again. The soot burns completely and disappears without trace.

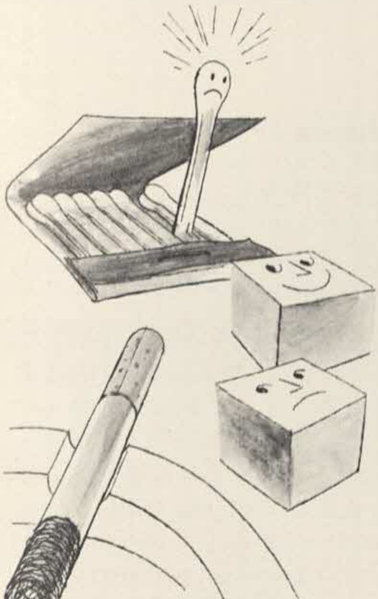
Can a sugar lump burn?

1 lump of sugar (a long one for preference)
1 peppermint
Matches
Some cigarette ash

Can a lump of sugar burn? Just try it—experience is the best teacher, as a wise man once said. Hold the sugar lump above a burning match . . . No, you cannot possibly get the sugar to catch fire this way. Did you murmur something about your fingers? Rub some ointment on them and next time be more careful!

Don't bother to try it again for, really, it won't work. Unless . . . No, I won't let you into the secret yet, but the best thing to do is to bring someone else into it and say: just try to set a lump of sugar on fire with a match. And when he has tried in vain you say: how stupid, for there is nothing to it. You take another sugar-lump, hold it over a burning match and . . . there, the sugar catches fire. How?

Here's the secret: ash. Cigarette ash. Without letting the other person see you, you dipped your sugar-lump into an ashtray with some ash in it. A lump of sugar with a bit of ash on it will soon catch fire from the flame of a match. It burns very well, with a mysterious blue-green flame, spluttering violently and giving out hundreds of little bubbles of molten sugar—just like a miniature firework. It probably does not burn away completely, the flame goes out about halfway. Let the lump cool down—for it is very hot and you could give your tongue a nasty burn—and then taste it. A sweet and tasty end to a firework, because your sugar-lump tastes of . . . caramel! Hmmmm!!



You can do the same experiment with a peppermint. You will wonder: how is it that a peppermint or a lump of sugar can burn with the aid of a bit of ash?

This simple experiment isn't easy to explain. But it comes to this—the ash acts as a catalyst. A catalyst is, in chemistry, a substance which can speed up, or slow down, a chemical action without actually taking any part in the reaction itself. So with ash as the catalyst a sugar lump or a peppermint can burn quite well!

Wool, cotton or nylon?

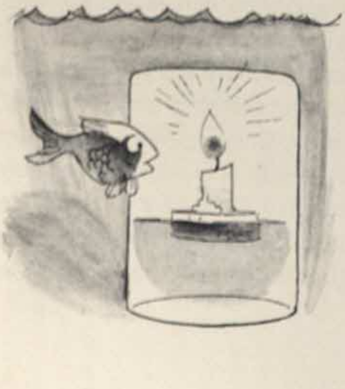
A variety of rags or threads of cotton, linen, wool, nylon, rayon and silk
1 lighted candle

You can quickly discover which is which of a number of unknown textile threads by holding them in a flame, unless one single thread consists of different kinds of textile spun together.

Cotton and linen burn quickly and easily, and smell like burning paper. Wool is not so easy to set on fire. It burns slowly and smells of burning hair or feathers, or—if you have a little imagination—like roast chicken. The ash which is left is hard and grainy. Pure nylon will not burn at all unless inflammable dyes or stiffening materials are mixed with it. Hold your nylon above the flame, it melts and turns brown. Acetate rayon burns with a luminous flame and melts; this kind of artificial silk changes into a knob which slowly hardens. Pure silk burns very slowly and smells just like burning wool, hair or feathers, but you will not find it difficult to distinguish silk from wool.

How can a candle burn under water?

1 candle or nightlight
1 cork or piece of wood
1 bucket full of water
1 large glass jam jar or preserving jar



'Never!' . . . 'Sure!' . . . 'Nonsense!' . . . 'Certainly!' . . . That is how the argument goes between Jack and Peter when one maintains that a candle can burn under water and the other violently disagrees with him.

When a debate has become reduced to terms like 'True!' and 'Rubbish!', the most sensible thing to do is to end it by carrying out an experiment—one which will show that the candle can burn under water, provided enough of the essential oxygen is available.

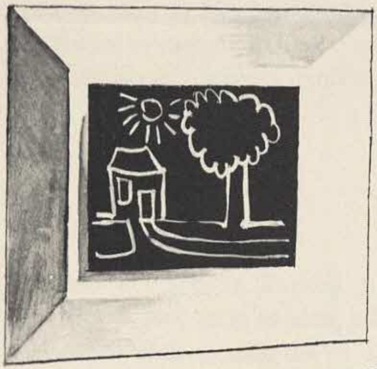
Fill a bucket with water and lay on the water a large, flat cork or a small board on which you have placed a stump of candle or a nightlight. Make the candle secure with a little melted wax. Light the candle and hold over it an inverted jam jar, or better still, a large preserving jar. Push the jam jar straight down into the water in the bucket and you will see the burning candle going down with it, still burning, thanks to the air remaining in the jar. But eventually the flame dies down and goes out. The oxygen is nearly all used up, but as long as there is enough oxygen the candle continues to burn under water!

What superb soot!

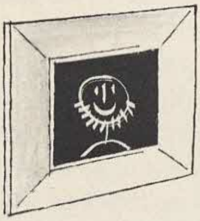
1 tin lid
Turpentine
1 piece of cotton rag
1 piece of glass
1 small saucer
1 needle
1 jam jar

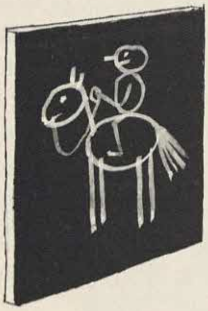
Sometimes it is useful to be able to get a bit of soot. For instance, at an eclipse of the sun, you need a piece of glass coated with soot so that you can watch it safely. Or if you want to draw some very fine lines . . . I'll tell you more about that later on. In the days when people used oil lamps it was very easy to coat something with soot, for by turning the lamp up a little you could produce as much as—or more than—you needed. Nowadays one of the most convenient ways of producing a supply of good soot is to burn turpentine. Pour a few drops of turpentine into a tin lid, and lay in it a bit of cotton rag so that it leans against the edge of the lid. Hold a lighted match close to the rag and the turpentine starts to burn quietly, giving off jet-black smoke—simply a cloud of soot. When black smoke comes out of factory chimneys it shows that the boilers are not being properly stoked, for the fuel which is being used is not burning completely and much is being wasted.

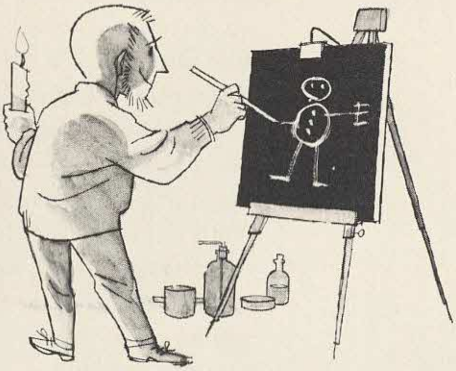
It is to our advantage, however, that our turpentine does not burn completely, for it provides us with beautiful jet-black soot. You can collect this soot by holding a jam jar over the smoking



flame; or, similarly, you can coat a white saucer, an old plate or a piece of glass. You can draw on the latter very easily, using a sharp-pointed piece of wood, a dry pen or a needle. If you hold a drawing made in this way up to the light you will be delighted with the effect. You can 'fix' your smoke engravings so that they don't smudge by using a solution, obtainable from art shops, which you spray on.

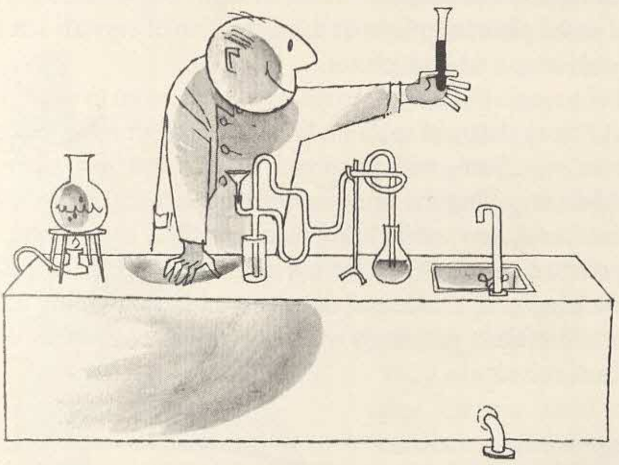






But don't forget to do your burning of turps in the open air. The smoke would make a nice, clean ceiling filthy in no time.

Chemistry



A stalactite grotto

2 glasses
Warm water
Epsom salts
1 cotton thread
1 plate

Have you ever seen a cave of stalactites and stalagmites? Isn't it a wonderful sight? The most impressive ones that I have ever seen are the Carlsbad Caverns in the State of New Mexico—a fairy palace underground! There is a chamber over half a mile long, 600 feet wide and more than 300 feet high—higher than the largest cathedral in the world. From the floor rise thousands of stalagmites, some as thin and sharp as a knife, others like totem poles, gothic towers, minarets and pagodas. Some of them are as much as 3 feet thick and over 30 feet high. From the roof, too, hang countless glistening stone needles, like icicles but much bigger, in delicate shades of soft pink, yellow and green.

These stalactite formations are due to the lime-charged water that drips from the roof. As the water evaporates it leaves, on the spot from which the drops fall, a minute layer of lime crystals. This layer grows extremely slowly—a single centimetre, not in a year, but in a century—into these enormous formations. The formation of the Giant Dome, 60 feet high, in the Carlsbad Caverns has taken

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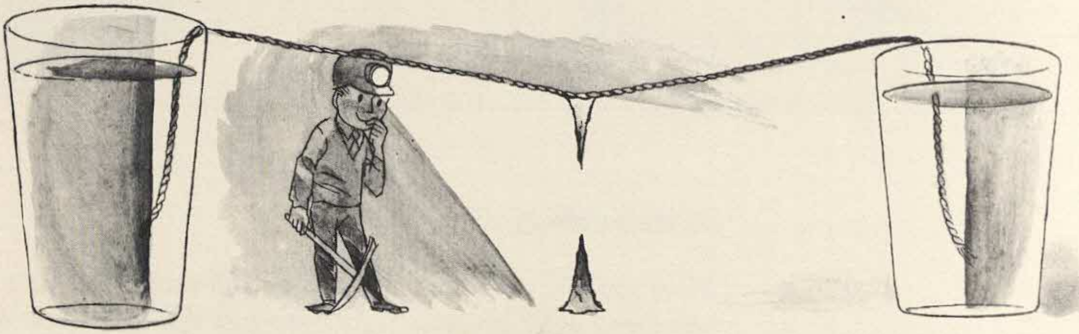
at least ten million years. We can imitate the formation of stalactites and stalagmites on a small scale.

Fill two glasses with water and dissolve in them as much Epsom Salts (magnesium sulphate) as possible. Put the ends of the thread into the glasses and under the lowest point of the thread put a plate. By capillary action the solution travels along the thread and drips from the lowest point on to the plate. If this happens slowly enough and the surroundings are warm enough, evaporation at the thread and at the plate brings about the formation of crystals which resemble stalactites and stalagmites.

Instead of a single thread you could use a twisted strip of cotton material. As more drops of solution fall from it from more places, more objects will form, widely spread out. If you can make a good few of them, giving the solution different colours, combining the different formations and lighting them with tiny bulbs you can make a miniature grotto. With two mirrors at an angle of 90° you can give the illusion of a wide and deep space in a fascinating way. You could also make a peepshow with a sparkling pool—that is, a small piece of mirror.



How to make casein glue

1 earthenware or china bowl
1 enamel saucepan
Some skim-milk
Vinegar
Sodium bicarbonate (baking soda)

One of the oldest and still most important kinds of glue is casein glue. Thousands of years ago the Egyptians used it and objects glued with it, found in tombs, are still in perfect condition! It was also used a great deal by the furniture makers of the Middle Ages.

Pour a pint of skim-milk into an enamel saucepan and add a cup of vinegar. Heat it up and stir it until lumps form; then pour the coagulated milk into a bowl. Let it cool right down and you will have one large lump at the bottom covered by a thin liquid. Throw the liquid away and add to the lump a quarter of a cup of water and a teaspoonful of sodium bicarbonate. The chemical reaction which then takes place produces the glue with which you can stick excellently. Try it and see!

Success assured

1 lemonade or similar bottle
Water
Tincture of iodine
Some hypo (sodium thiosulphate)
Glue

If you are taking part in some kind of show and would like to mystify your audience with some scientific experiment how about changing a coloured solution into plain water? 'Changing wine into water' was a common trick in the old days, but as wine is not an everyday drink in most households these days we will have to choose something which is more familiar. Coca Cola or any of the dark, red-brown soft drinks will do. Change Coca Cola or something into water? Is it possible? No, of course it isn't, but there is no need for your audience to know that. You prepare something that can hardly be distinguished from Coca Cola in appearance. Fill an empty Coca Cola bottle with water to which you have added enough Tincture of Iodine to give it the right colour.

Now you must fasten a crystal or two of hypo to the underside of the crown cork. Hypo, known officially as sodium thiosulphate, is what photographers use to fix their photographs. Any photographer, I am sure, would willingly let you have a crystal or two. They can be fastened to the underside of the stopper with a little glue. Or you could put some crystals in a tiny bag made of thin porous paper held under the stopper. When you have prepared the stopper replace it carefully on the bottle.

When it comes to your turn in the show you have nothing more difficult to do than to give your Coca Cola bottle a really good shake to turn it into plain water. The shaking makes the hypo mix with the iodine solution, with the result that the brown colour disappears like magic!

Don't forget to wash the bottle out thoroughly very soon after you have performed this trick.

Write your name with hypo

1 watercolour brush
Paper
Tincture of iodine
Hypo

If we have some tincture of iodine and a little hypo handy we can carry out another delightful experiment. Make a sheet of paper brown by brushing it all over with the tincture of iodine. Dissolve a little hypo in water to make a fairly strong solution, dip the brush into the solution and you will be able to write your name in a most unusual manner. For, where you touch the brown paper with the brush, the brown disappears and you seem to be writing your name with absolutely clear water! Your name appears in white letters against a brown background.

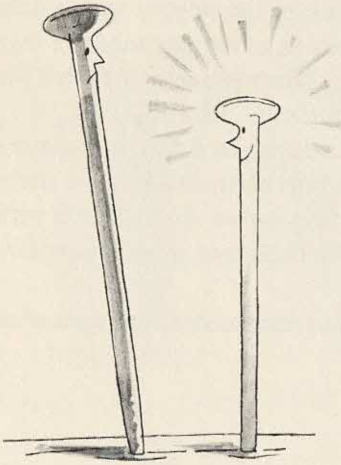
Iodine spots have the reputation of being very difficult to remove. In fact, nothing could be further from the truth. They vanish in a twinkle if dabbed with a little water in which a few crystals of hypo have been dissolved.

The hypo solution and the tincture of iodine together form a colourless compound. You can exploit this beautifully if you intend to give some kind of science show. At the start of your performance, hang up a piece of paper coated with the iodine, show your clear solution as though it were water, dip the brush in it and write the words 'SCIENCE SHOW'.

Coppering nails

A few ordinary nails
Copper sulphate
1 dish or bowl
Water

Metals can be arranged in what is known as the electrochemical series. Each metal in the series replaces a metal lower in the series from a solution of a salt of the latter, and goes into solution itself. Iron provides a good example of this with the lower-placed metal copper.



Dissolve some copper sulphate crystals in water in a small dish. Distilled water is best for this if you can get it. Ordinary tap water will probably make a cloudy solution which you will have to filter through blotting paper or allow to stand to settle. Then pour off the clear solution on top, and use that.

Lay some clean, rust-free nails in the solution. If necessary clean the nails with emery cloth. The iron replaces the copper from the copper sulphate solution, going into solution itself. The result is that the nails become covered with a thin layer of copper while a small amount of iron goes into solution, forming iron sulphate.

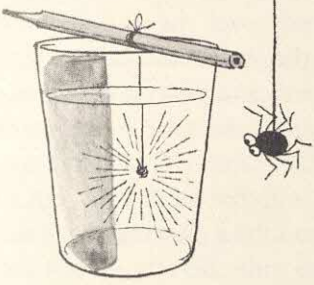
If you put a well-cleaned piece of real tin into a solution of silver nitrate it becomes covered with a layer of pure silver and forms what is known as a silver tree—with sparkling, glistening silver leaves!

ELECTROCHEMICAL SERIES

potassium
sodium
calcium
magnesium
aluminium
chromium
iron
nickel
tin
lead
copper
mercury
silver
platinum
gold

Growing a big crystal

Some alum powder or crystals
2 glass jars or bowls
1 pencil
1 piece of thread
1 narrow glass



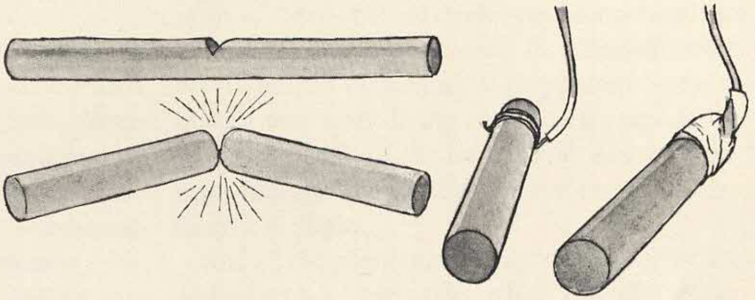
If you would like to try to grow a large crystal, here is what to do. Stir powdered or crystal alum into some warm water until no more will dissolve. Pour off the clear liquid into another container so that the undissolved alum is left behind. Let the liquid cool. When some crystals have formed, pick out the largest and add to the solution just as much alum as you have removed. Warm the solution very gently until the added alum has dissolved. Let the solution cool again and pour it into a small glass or jar. Tie the crystal which you removed to a piece of fine thread and hang it in the solution from a piece of pencil. Stand the jar in a place free from vibration and where you can leave it undisturbed for a week or two. Then, as the days go by, you will be able to watch the crystal gradually growing bigger.

Electrolysis of water

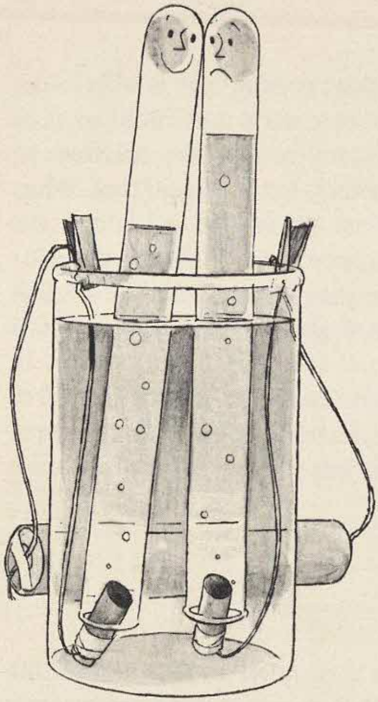
1 flashlamp battery
Copper wire
1 old battery
1 glass or jam jar
2 test tubes
Water
Soda
Matches
1 wooden splint

As you probably know, water is a chemical combination of the gases hydrogen and oxygen, and H_2O merely means a combination of two H (hydrogen) atoms with one O (oxygen) atom. With the help of electricity it is possible to split the liquid, water, into the gases oxygen and hydrogen. This process is called electrolysis.

From an old torch cell pull out the carbon rod, file a nick in the middle of it and break it into two pieces. Fasten to the end of each piece the bared end of a length of insulated copper wire. Wind the other ends of the wire, also bared, round the terminals of a $4\frac{1}{2}$-volt flashlamp battery, or three $1\frac{1}{2}$-volt cells connected in series (as in the illustration on page 66, bottom left).



Dissolve a handful of washing soda in half a pint of water. Fill a jam jar with this solution, and also fill two test tubes (empty bottles of suitable size and shape will serve the purpose). Holding your thumbs over the ends of the two tubes, invert them into the jar of soda solution. Remove your thumbs, and put the carbon rods

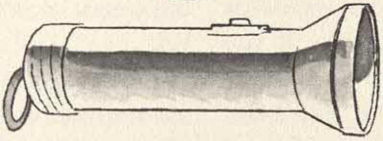


underneath as the picture shows. A couple of clothes pegs may be useful to hold the wires steady.

Bubbles start to rise up the tubes. From the rod which is connected to the positive terminal of the battery, oxygen bubbles rise; from the other comes hydrogen—twice as much. This gives us evidence that the formula is correct. But how can you be sure one is oxygen and the other hydrogen? Wait until both tubes are full of gas. Then, with your thumb firmly over the end of the tube which filled first, remove it from the water and hold a lighted match close to it. Remove your thumb and you may hear quite a loud bang. On the other hand, the gas in the tube will more likely burn with a quiet, almost invisible flame. This confirms the presence of hydrogen. Do the same with the other tube, but when you remove your thumb put into the tube a glowing (not flaming) wooden splint: it re-lights and burns quite fiercely—a test for the presence of oxygen.

There are factories which produce hydrogen and oxygen on a large scale by a similar process of electrolysis. The gases are compressed into cylinders which are then sold for all sorts of purposes.

Light



Some light on light

Light is part of our everyday lives—something so familiar that we almost never give it a thought. Yet light is one of the most wonderful phenomena of Nature that we know.

What is light? In a few words, it consists of electromagnetic waves radiating from some source such as the filament of an electric bulb. More precisely, we could describe these rays as a succession in space of positive and negative electric fields moving at right-angles to alternating magnetic fields. If you feel that this sounds a bit too difficult to follow, just remember that light can also mean pleasure—as, for instance, when the sun shines again after a series of dull, grey or rainy days!

What is the cause of light? It is caused by the electrons spinning round the nuclei of atoms. The electrons circle round each nucleus, at various distances from it, as the planets go round the sun. If energy is supplied to the atoms—say, in the form of heat—the electrons can jump from the inner orbits to the outer ones. But these electrons find it difficult to maintain their positions—it is as though they were living above their stations. So they jump back to the inner orbits again, at the same time giving up their excess energy in the form of . . . light.

And all the phenomena of light, whether we are dealing with a glow-worm, a fire, a candle, a light bulb, a neon tube, a flash of lightning or a star—all have their origin in the jumping of the electrons from the outer to the inner orbits around the nucleus. This may seem strange, but nevertheless it is true.

The fastest possible speed

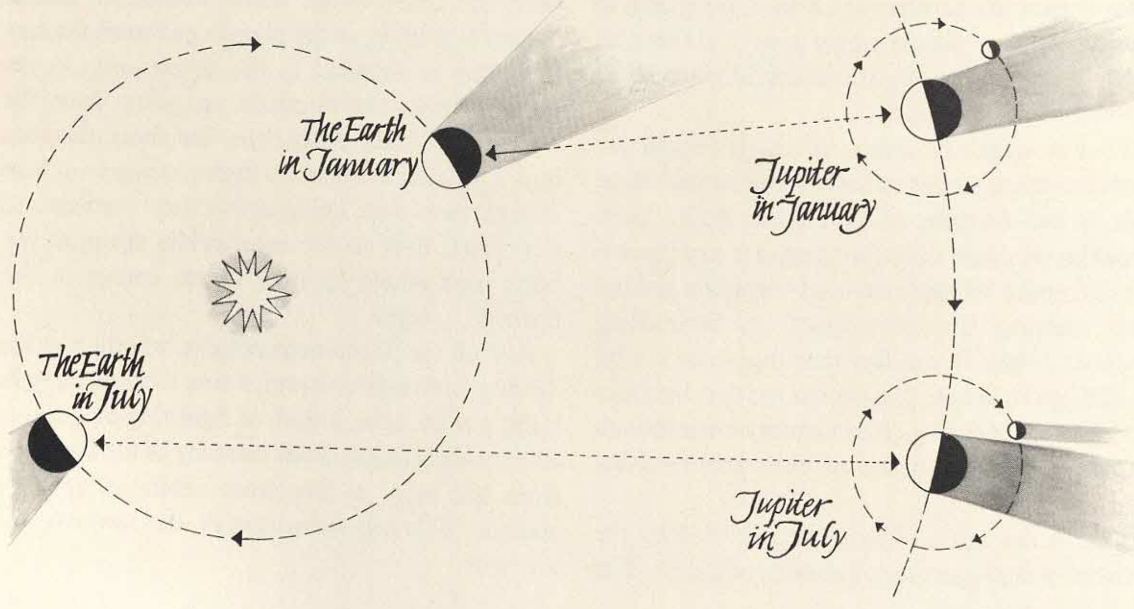
According to Einstein's Theory of Relativity, no greater speed is possible than that at which light waves travel: 186,000 miles per second. This means that if a photographic flash-bulb is exploded at the top of a hill 10 miles away the light reaches our eye in $\frac{1}{18,600}$ of a second, which, to all intents and purposes means that it is instantaneous. Yet by astronomical standards 186,000 miles a second is a mere trifle, if you realise that the nearest star is two and a half million million times as far away as our flash-bulb, and that there are star systems millions of times even farther away from us. In spite of the unimaginably high speed of 186,000 miles per second the light still takes millions of years to reach us. If one of these distant stars had disappeared a million years ago you would still see it, for the light from it that you see started on its travels long, long ago. If . . . *if* you could move faster than light, and then stop suddenly and turn round, you would be able to see yourself coming. . . .

In 1675 the Danish astronomer Römer made a fairly accurate estimate of the speed of light—quite an achievement for that time. He had noticed that the times between the disappearances of the moons of Jupiter behind that planet were shorter or longer according to whether the distance from the earth to Jupiter was smaller or greater. As is explained in the drawing, this happens because the light needs more time to cover the greater distance from Jupiter to the earth. Now, Römer already knew the different distances, so that by measuring the differences in the times he was able to calculate the speed of light.

I expect you can understand how a wave on water spreads out as it moves forward. Is the same thing possible with light? When a star explodes in a cloud of dust, forming extremely bright stars ('novae'), it is possible to record the expansion of the illuminated area, and so the progress of the light, by a succession of photographs.

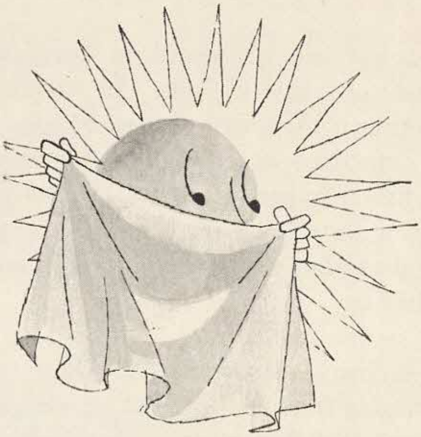
'Relativitively' straight

Light travels in straight lines, but when the rays pass close to some massive object with a large gravitational field, such as the sun, they are attracted and bend a little. Einstein, in his Theory



of Relativity, held that this would be so; but many learned scientists doubted it. Consequently the whole scientific world waited with excitement on the 29 May 1919 when an eclipse of the sun would enable Einstein's ideas to be tested. What the scientists needed to measure was a change of less than $\frac{1}{2000}$ of a degree in the direction of the light—comparable to the breadth of a finger observed by the naked eye at a distance of one mile! An English expedition in Brazil succeeded on that memorable day in photographing two stars during the total eclipse which, at that time, were actually behind the sun's disc. Because of the bending of the rays by the sun's gravitational field the stars became visible. So the men had seen behind the sun, and the deviation agreed with what Einstein had predicted. For the supporters of the Relativity Theory this was a resounding triumph.

What gives light its colour? The number of waves sent out in one second by the light source. In other words, the frequency with which the waves follow one another. If this is about 400 million per second the light is red; at 800 million waves a second the light we see is violet, and the wavelengths between these two figures include the successive colours of the rainbow. These different numbers, and the colours they represent, depend upon the size of the jumps that the electrons make inside the atoms. Moreover, for each chemical element these jumps are different, with the result that each element emits a characteristic combination of colours. On the other hand, each element can also absorb the same range of colours. By analysing the light from a star, therefore, scientists can discover what elements are present in it, even though the light may have taken thousands of years to reach the earth. In the last century the inert gas helium was discovered on the sun before it was discovered upon the earth! By this same method, spectrum analysis, it is also possible to determine the speed at which some of the star systems are moving away from the earth.



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Lasers, the wonder-rays

In 1960 scientists succeeded in producing a completely new kind of light. The wonder-ray, that favourite of the writers of science fiction in all sorts of situations—as a death ray, as a means of starting fires from great distances, for extinguishing fires or for transferring energy—belongs no more to the realms of science fiction. It is now an established fact.

What is this wonder-ray? It consists of light waves—ordinary electromagnetic waves—light waves ranging from the infra-red wavelengths to visible light. Well then, what is so wonderful about it? With this kind of light it is possible to direct a beam at the moon of such intensity that the reflected light can be detected. The light of the wonder ray is thousands of times stronger than from any other form of light. With it a hole can be drilled in a steel plate in $\frac{1}{1000}$ second, and any materials, including diamond and tungsten, can be vaporised. With such a light ray the most complicated signals, or the spoken word, can be sent out across practically unlimited distances, if need be into deep space, which will be of great importance for space travel. Medical operations can be carried out with it which hitherto have been impossible.

It would be possible to produce a frightful 'death-ray' with a range of scores of miles which would destroy aeroplanes and rockets. That sounds wicked and it is wicked.

It will be possible to obtain temperatures of millions of degrees capable of converting all materials into 'plasma'—a disorderly swarm of electrons and nuclei. Both in the laboratory and across astronomical distances it will enable scientists to measure with an accuracy which was unthinkable only a short while ago. It will be possible to devise completely new methods of telephonic communication whereby hundreds of thousands of telephone conversations will travel underground through a single plastic tube. And one of the dreams of engineers may be realised, the transmission of energy over great distances without the use of wires or cables, even to artificial satellites and space craft. In short, such incredible things are within our grasp that to speak of a 'wonder-ray' is really no exaggeration.

Will it need vast quantities of equipment to generate this wonder-ray? Not at all. Such a ray, with somewhat limited possibilities, can be produced by a small rod that you could hide easily in the palm of your hand. A rod that consists of nothing much more than a small rod of synthetic ruby crystal—a 'laser'.

It's remarkable that a ray with such properties can be produced by a simple rod of ruby and, moreover, consists of something which has been known so well for so long: electromagnetic waves. What is the secret of the light ray produced by the laser? It is this: the light waves from it are *coherent*; that is to say, not only are they all of exactly of the same wavelength, but they are absolutely *in phase*. This means that they travel in step like marching soldiers.

This coherence is a unique property, for, before the discovery of the laser in 1960, coherent light had never before been produced: never on earth and, probably, never in the whole universe. All the light that we know is incoherent, or non-coherent.

All the usual sources of light such as a candle flame, a bulb or the sun emit light consisting of a mixture of long and short waves—forming white light. Even the so-called 'monochromatic' light, light of one colour only, such as a sodium lamp emits, is actually a mixture of waves of different lengths. Moreover, in none of these sources of light is there any question of coherence. It is impossible to concentrate the light from any of these to a really fine point by means of a lens or a concave mirror. But this coherent light from a laser can be concentrated to a point less than $\frac{1}{10,000}$ millimetre in diameter. All the energy emitted by the laser falls on this minute area. No wonder, then, that such a beam makes all materials vaporise and that it makes possible temperatures of millions of degrees.

A beam of ordinary light always spreads out when it travels over large distances, but with coherent light it is possible to have beams which remain almost parallel all the way. This is why it has been possible to direct a beam of light to the moon and receive a reflected beam. The beam arrives back after 2½ seconds, for that is the time it takes for the light to make the 500,000-mile trip there and back.

Coherent light can be concentrated into a ray thousands of times finer than a human hair, and steel plates can be cut with it. This opens up untold possibilities for the metal industries, and above all for the manufacture of micro-miniature structures for which the finest metal tools would be too clumsy. Likewise, the laser's extremely fine beam can be used simply and rapidly for certain surgical operations such as the destruction of a tumour in the eye.

The name laser comes from the initial letters of '*l*ight *a*mplification by *s*timulated *e*mission of *r*adiation'. The laser is, in fact, able to amplify (or strengthen) light, if necessary, millions of times—another unique property, for the amplification of light had previously been impossible. But the most fantastic possibility of light rays emitted by the laser is that these coherent light waves can, just like radio waves, carry radio and television programmes and telephone conversations. What is more, they can take a simply enormous 'load': a coherent light ray, far finer than a hair, is capable of carrying simultaneously scores of television programmes and hundreds of thousands of telephone conversations.

Sunlight—the life-giver

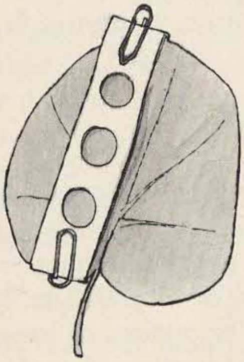
One last word—not about the modern marvels of lasers but about the ancient marvel of sunlight. Don't forget that all our daylight, even the cold, dim light of a winter's day, is really sunlight. The sun is all-important for us: without its warmth and light the earth would be just a cold stone ball without life of any sort. And isn't life the greatest and most beautiful wonder we know?

The marvel of photosynthesis

1 geranium plant
Strips of black paper
Paper clips
1 pair of scissors
Boiling water
Methylated spirits
A few bowls
1 saucepan
Iodine solution

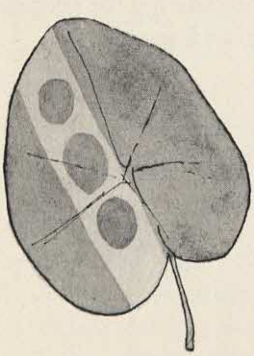
In the field of chemistry ordinary plants achieve things which the cleverest chemists working in the finest laboratories cannot better. Plants are able to build up starch, sugar, cellulose and fat from air, water, and mineral salts from the ground. On account of the fact that light plays an important part in this process we call it photosynthesis. Every plant is a chemical factory—as intricate as it is astonishing.

The green material in the leaves—chlorophyll, which actually means 'green-leaf'—is able, with the aid of sunlight, to make the water and air combine to form sugar and then starch. We can show by experiment that light is essential for this.



Stand a geranium plant in the dark for a few days and then, with paper clips, fasten some strips of black paper with a few holes cut out of them to both sides of a few of the leaves. Now stand the plant in sunlight for a few hours.

Pick the leaves which have been partly covered, remove the strips of paper and then kill the leaves by dipping them in boiling water for about a minute. Next, put them into a small dish of methylated spirits. Stand the dish in the boiling water, making quite sure that there are no naked flames about. The warm alcohol removes the chlorophyll from the leaves and they turn quite white.



When they have reached this state remove them from the meths and lay them out gently in a white dish. Handle them carefully, for they will be rather brittle. Rinse them carefully in plain water until they are soft again.

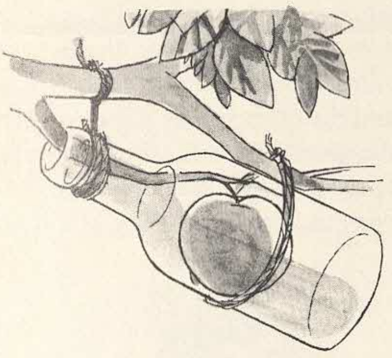
Now pour over them some iodine solution, made of one part of tincture of iodine to ten parts of water. The parts of the leaves which were exposed to the light turn a very dark blue, almost black, indicating the presence of starch. The unexposed parts merely turn brown, because the sunlight could not reach them, and no starch was made there. So we have been able to show that sunlight is essential for the formation of starch in leaves.

Scientific fun with apples

1 apple tree with green apples
1 bottle
String
Petroleum jelly
Aluminium foil

Anyone who happens to have an apple tree with some unripe apples on it can play a couple of delightful practical jokes—with a scientific basis of course!

In the first place you can demonstrate the mystery of the apple in the bottle which will make anyone who sees it ask in amazement how on earth it was done. How is it possible to get an apple in a



bottle with such a narrow neck? A real poser. The solution of the mystery is that the apple grew inside the bottle.

Choose a strong branch bearing a small unripe apple which will pass easily through the neck of the clear glass bottle. With string, and if necessary a stick as well, tie the bottle to the tree. Nature will do the rest, and if you have enough patience you will eventually have a large ripe apple inside the bottle. How your friends and relations will stare!

Now for a name on an apple. To do this, cut letters from aluminium foil and stick them on an unripe apple with petroleum jelly or some waterproof adhesive. Make sure that you stick the letters to the side of the apple which is exposed to the sun, for that is where it will work. The rays of the sun cause chemical reactions to take place in the skin of the apple causing the skin to turn red. This will not happen on places which the light cannot reach—the skin beneath the foil.

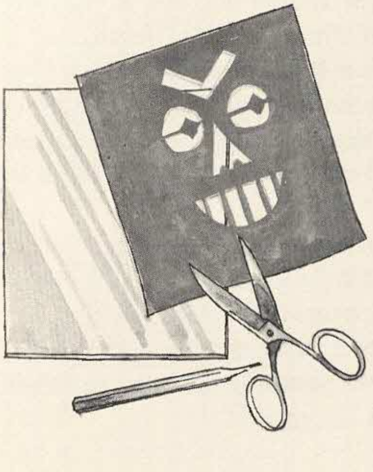
When the apples have ripened to a nice red, pick them off the tree, remove the foil letters, wash the apple clean and there stands the name in the skin—signed by the rays of light.

This idea can be used for making other designs on the skin of an apple. Decorations, or eyes, a nose and a mouth and ears. The sun will do the rest.

A ghostly shadow

1 bright lamp
1 mirror
1 sheet of cardboard or paper
1 pair of scissors

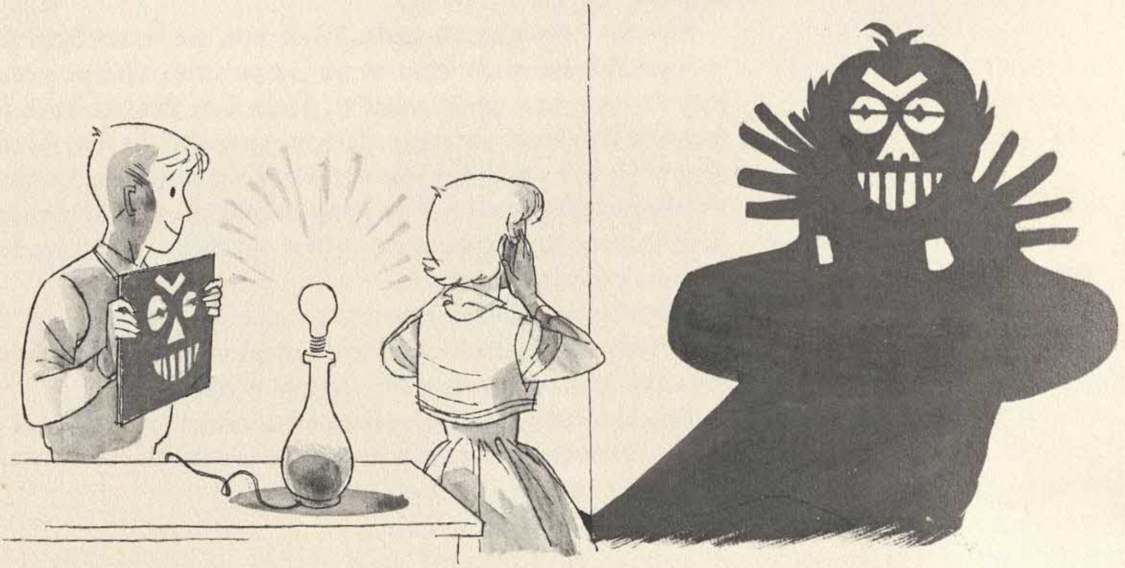
A bright shadow . . . yes, it's possible! For this rather lugubrious demonstration you will have to use a lamp with a clear bulb, for with a pearl or frosted bulb you will not be able to get a sharp shadow. If somebody now stands between the lamp and the wall—like the girl in the drawing on the next page—a shadow of the head and part of the body is formed on the wall. Now the idea is to cause a pair of ghostly eyes, a nose and teeth to appear as if by magic in this dark shadow. You can do this with the help of a mirror and a piece of paper on thin card with holes cut out.



On the paper or card draw the eyes, the nose and the teeth as shown in the drawing. Then cut them out carefully and lay the paper on the mirror. The mirror must now be held firmly so that the spots of light which the mirror throws upon the wall fall precisely on the shadow of the head. The spots of light form the eyes, nose and teeth of the shadowy head and give it a nice creepy appearance. The contrast between light and dark in the ghostly illusion is best if the paper or card is dark in colour. Brown card or paper is most effective.

You can make your demonstration even creepier by having two mirrors, one held on each side of the lamp and of the person casting the shadow. One of the mirrors has only the nose and teeth cut out from its piece of paper, and the other has only the eyes cut out. Now it is possible to make the spots of light for the eyes move separately from the nose and teeth—horrible, don't you think?

Or are you laughing at it? As you like. Laughing is good for you.

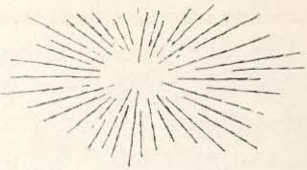


Red gives green, blue gives yellow

Sheets of paper of different colours

Perhaps you have noticed that ordinary lamplight looks quite pink after you have been looking at the television for some time. That is because the picture on the screen is bluish and your eye, after looking at this colour for a while, interprets the white-yellow light of the lamp as pink. In this respect the eye is not very reliable. If you look at a sheet of white paper in the shadow at midday when there is a blue sky, it is bound to have a bluish tinge —but it looks white. If you look at the white paper on a cloudy day an hour before sunset, it will be slightly orange—but it will look white. This is logical, but if you don't believe it, you can test it by taking colour photographs!

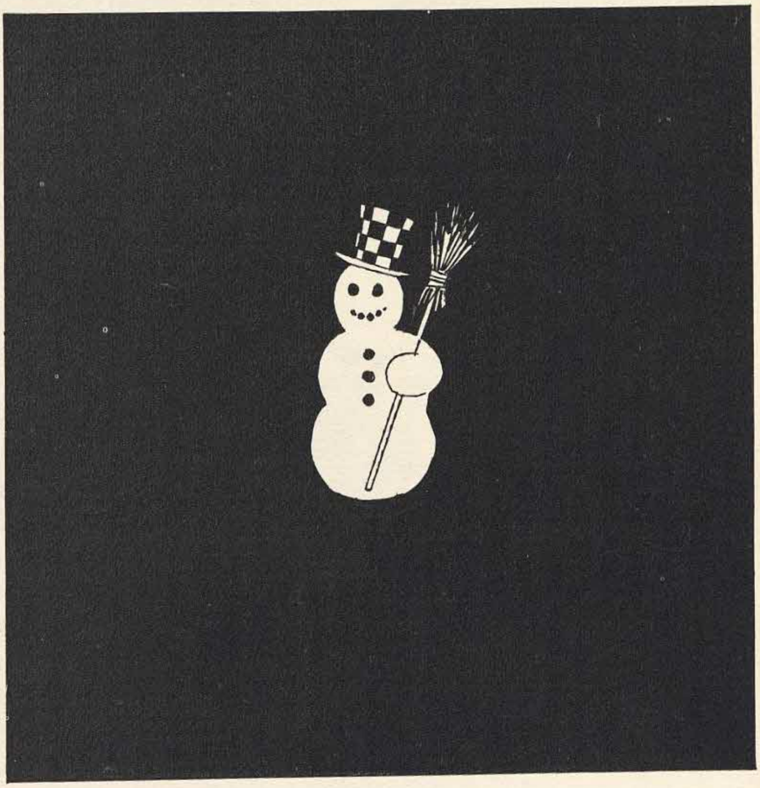
Take a strip of light grey paper, lay it on a large sheet of green paper or a green cloth and stare at it for about a minute. You will observe that the pale grey paper appears to be pink. Lay the piece of grey paper on a sheet of bright blue paper and after a short while the grey now looks orange-yellow. Similarly the grey on bright yellow looks . . . blue, and on red . . . green!



The wonderful way in which the eye reacts to colours can also be observed if, in a room strongly lit by sunshine, you stare for a few minutes at some red object lit by the sun. Now look suddenly up at the white ceiling and you will see an area with the shape of the outline of the object but coloured . . . blue-green or green. By looking at a green area you can see a violet or pink patch on the ceiling. With a blue area you get yellow or orange. These little experiments work best if between looking at the object and looking up at the ceiling you close your eyes. Try looking at a surface covered with different strong colours, something like the dust jacket of this book, and then look up at the ceiling. Then be prepared for a surprise!

So yellow gives blue, while blue gives yellow or orange. That is not accidental, for the colour which you see on the ceiling is always the complementary colour of the one at which you have been looking. What are complementary colours? You can find this out by doing the following experiment.

All these experiments must be done in strong light. Look now for a minute at the drawing here of a snowman and then look up at the ceiling. There he is, our snowman, but no longer white, he is grey or even nearly black.

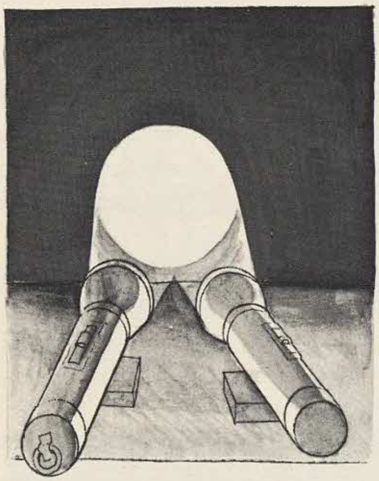


All colours make white

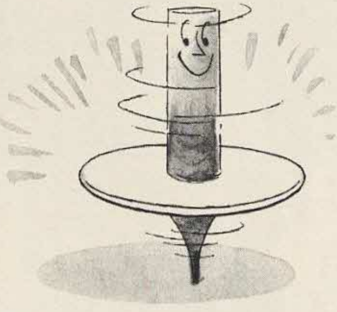
Paint or coloured pencils
White paper or card
1 red pencil
1 lens
1 mirror with a bevelled edge, or a prism
2 torches
Red, green, yellow, blue cellophane,
or ink or water-paint of these colours

As you know already, white light is made up of a mixture of colours. This is shown if, for instance, sunlight falls on the bevelled edge of a thick mirror or through a triangular piece of glass—a prism. In this way the sunlight is split up into its constituent colours, red, orange, yellow, green, blue, indigo and violet—the colours of the rainbow, which you can catch on a piece of white paper held to the mirror. Bring these different colours together again, with a lens for example, and you get white light again.

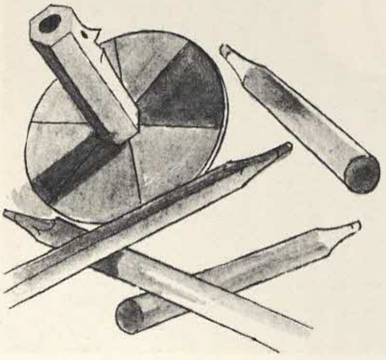
Take two torches and make the light from one of them blue and from the other yellow. You can do this by painting these colours on the torch glasses (using water-paints), or better still by fixing some coloured cellophane over the torches with rubber bands. Now let the light from the two torches fall upon the same part of a sheet of white paper or card. The blue spot of light and the yellow spot of light together give white, unless the light from one of the torches is too strong. In that case you must reduce the strength of one of the coloured lights. Try this again with other colours. You will find that there are more colours which will give white when put together. Two colours which together give white are called complementary colours.

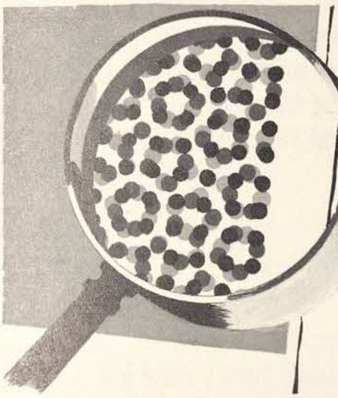


It is rather different if you paint a disc of stiff paper with alternate broad sectors of blue and yellow; you can use crayon, or ink, instead. Now spin the disc round very fast, perhaps by pushing a hexagonal pencil through it and spinning it like a top. You will not see the separate colours any longer, i.e. separate blue and yellow stripes, but green. For that matter you can also get green by mixing blue and yellow paints or inks together, or by laying one layer of coloured crayon or chalk over another.



What colour do all the colours of the rainbow together give? Make a disc of white paper or thin card with coloured sectors of red, orange, yellow, green, blue, indigo and violet. Push a pencil through the middle as before and then spin the disc. The disc can be made to spin fast enough to make all the colours mix well together—a result of the slowness of the eye. And then we see that these colours of the rainbow, when mixed together give . . . white or grey. Now the colours which you use are not as pure as the colours of the rainbow, and much depends too on how much of one colour and how much of another you have used. There is a chance that your spinning disc may have a pinky shade. Well, make another disc, this time with less red in it. We can understand then, how with the exact proportions of colours of the rainbow white is the result.





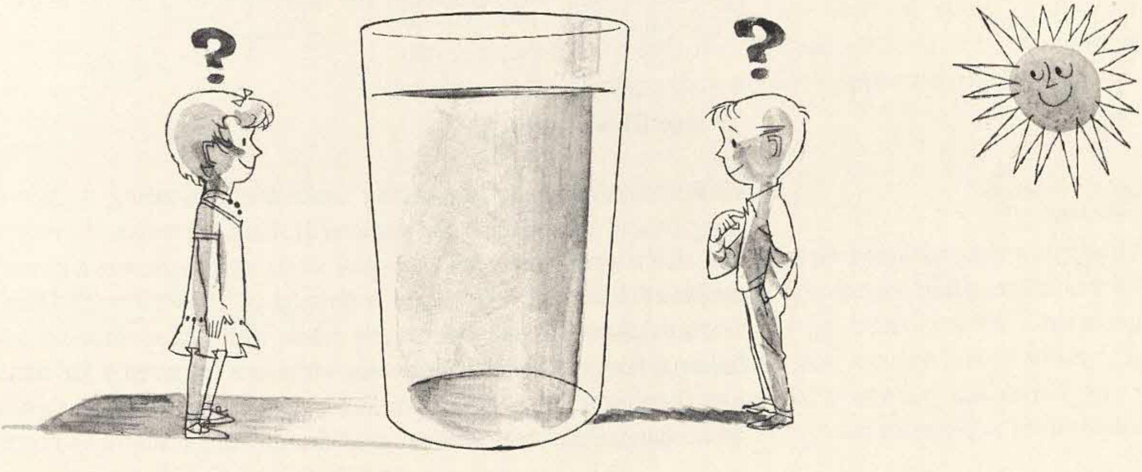
By the mixing of three colours it is quite possible to obtain all colours. It is on this principle that colour films depend. A colour film consists of three layers, each of which receives and reacts to only one colour in various intensities. The coloured plates and other coloured pictures which you see in books and magazines are usually printed with red, yellow, blue and black inks, as you can easily see if you look at such a coloured plate with a strong magnifying glass. Then you can see the tiny spots of red, yellow blue and black quite plainly. See for yourself how many different colours you can make with red, yellow and blue inks, paints, pencils and crayons.

Red or green?

Some red ink
Some mercurochrome (a red antiseptic dye which you can get from the chemist)
1 glass of water

What we are going to decide in this experiment is whether water in which you have mixed some red ink or mercurochrome is red . . . or green.

Of course, you will say, it is bound to be red or pink. But just try it. Stir a few drops of red ink into a glass of water. Now hold up the glass with the light behind it, and look through—the water is coloured pink. But hold it away from the light—the water is coloured . . . green! This happens because in the first case you were seeing transmitted light and in the second case reflected light. This experiment will not succeed with all kinds of red ink, but it will work well with a solution of mercurochrome, the stuff that is used for disinfecting wounds. Do not use too much mercurochrome—only with quite a dilute solution is the change from red to green most clearly visible.



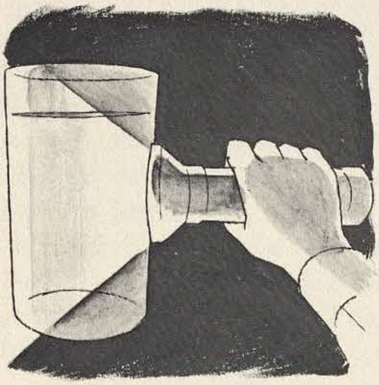
You can also get this example of 'dichroism' or 'two-colouredness' in another way. Drop into a dry, empty glass a very small amount of red ink or mercurochrome so that the bottom of the glass is wetted, and then let it dry. Now hold the glass horizontally, against the light, and look through the bottom. You will see red. Then turn the glass so that the red ink reflects the light at a very oblique angle, and you see green!

Why is the sky blue?

1 glass
Some water
Some milk
1 torch

Which is right: 'the sky *is* blue', or 'the sky *looks* blue'? The latter, because anyone who can orbit the earth in an artificial satellite sees the sky as blue-black. And even to us on earth, at sunset the sky looks red and yellow. Why, then, do we so often see the sky looking blue?

As we have seen, white sunlight consists of a mixture of different colours of light. Drops of water and specks of dust in the air scatter the blue rays most widely and let the other colours through unhindered. Yellow and orange, for example, can pass between the specks of dust very easily. This is the reason why, in foggy weather yellow or orange rays from car headlamps, or the sodium-vapour street lamps, light things up much more brightly than white light does.

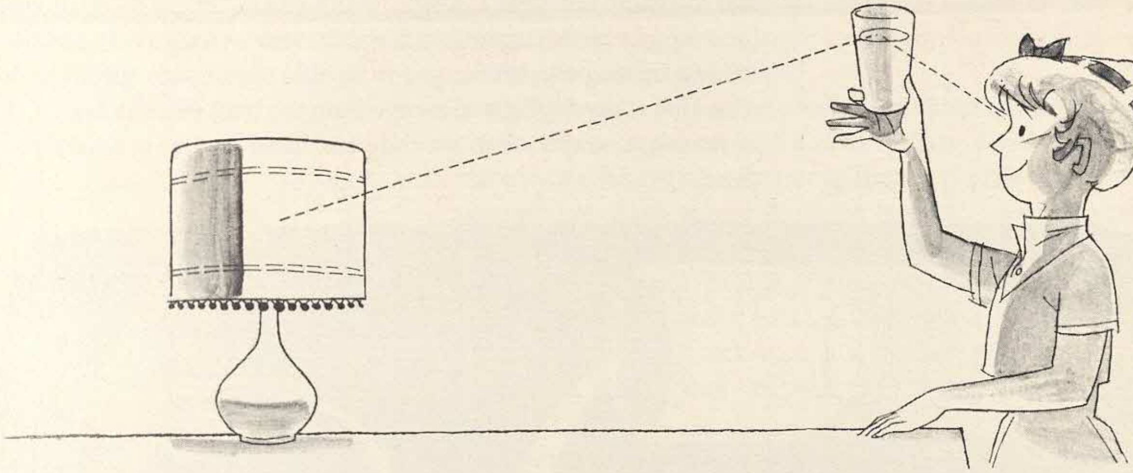


You can demonstrate that blue rays are scattered much more than the other colours by stirring a few drops of milk into a glass of water. The particles of milk then play the part of the drops of water or specks of dust in the atmosphere. Now hold the lighted torch against the glass in a darkened room, and look towards the side of the glass in a direction at right angles to the rays of light. The very dilute milk does not look white, but bluish, because the particles of milk have scattered the blue light-rays more than the other colours.

Water like mercury

1 glass of water
1 table lamp

Have you ever been swimming underwater wearing a pair of goggles, and looked up at the surface? If there are waves above you, and that is usually the case, it is just as though there was a moving carpet of cellophane above you, a moving carpet which produces a fantastically beautiful sight. And while you are swimming and looking, have you ever taken some air down between your hands and then let it escape?—The rising bubbles look like tiny shining silver balls. Often too, it looks as if the moving cellophane carpet,



which the rippling surface of the water so much resembles, is like a mirror—it's as though it was covered with quicksilver.

You can see this very beautifully if you fill a glass with water and then, like the little girl in the drawing, look up at the underside of the surface. Then the surface looks just as though it was made of silver or mercury. Try if you can see anything, for instance the table lamp, in this mirror. You must hold the glass quite still, otherwise the mirror will move.

How does the water-surface, viewed from beneath, act like a mirror? It happens because, when the light passes towards the boundary between the water and the air at an angle, if the angle is too oblique the light cannot escape from the water and get out into the air. It is reflected back into the water and passes through the glass, into the air and to your eyes.

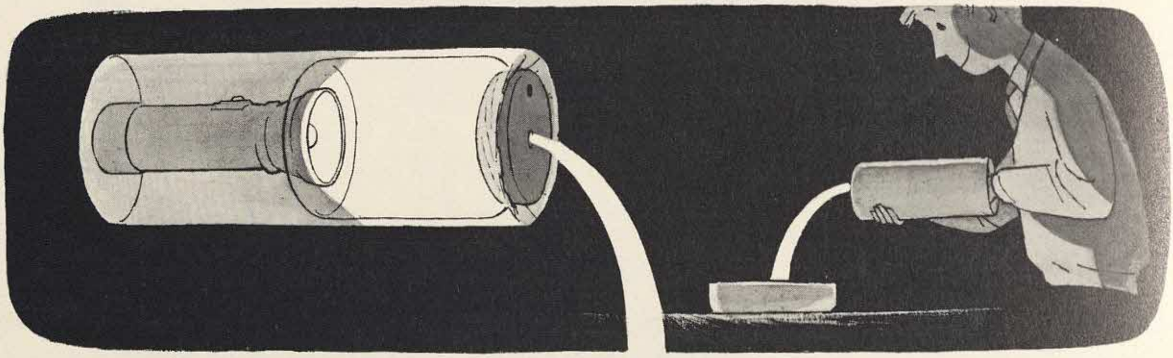
A person swimming under the water who looks upwards will find that he cannot look upwards at an angle to the surface and see through the surface, no matter how clear the water is. Of course this is a pity for the fish, for they can see so little of the beautiful world outside. Perhaps they wouldn't appreciate the view anyway.

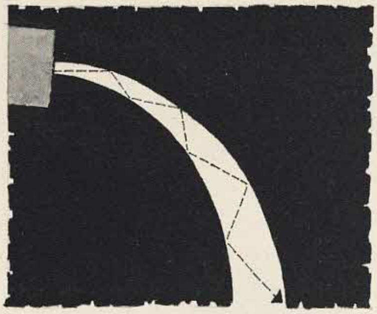
Light trapped in a water-jet

1 torch
1 jam jar with a close-fitting lid
1 piece of stiff brown paper or corrugated card
Tools

We know that a ray of light passing upwards through water which strikes the surface at an oblique angle cannot pass out; instead it is reflected back into the water as though from a mirror. This makes it possible to make rays of light follow a curved jet of water. The rays get trapped inside the jet and for a time they cannot get out.

Make two holes in the lid of the jam jar, a large hole in the centre and a smaller one near the side. Wrap round the jar a roll of stiff brown paper or corrugated card, about twice as long as the jam jar. It must be long enough for you to be able to put your torch inside it and not allow any light to escape from the back (see the drawing). If necessary wrap a cloth around your hand so that it is all light-tight.





You have filled your jam jar with water. Hold it slanting over the sink or washbasin with the torch on and the room light off. Put your finger into the stream of water, close to the hole, and you will see light falling on your finger. Now move your finger along the curved stream of water; light continues to fall upon your finger, even though the stream is bent through ninety degrees.

The second drawing, showing the course of the light inside the water-jet, explains how it all takes place. The rays of light are continually being reflected from the surface of the water-jet from one side to the other until they reach your finger and light it up.

In exactly the same way it is possible to lead light rays through a bent glass or plastic rod. Sometimes this device is used in advertising displays in a very attractive manner. Illuminated fountains owe their fascinating appearance to the imprisonment of the light rays inside the moving jets of water.

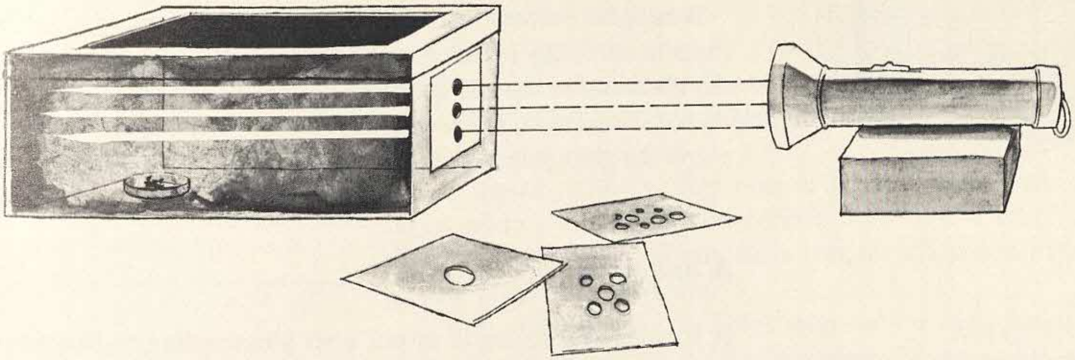
Light rays made visible

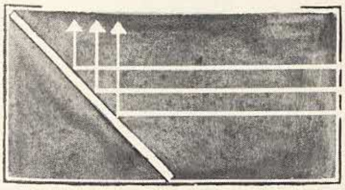
1 cardboard or wooden box
Black paint
3 pieces of glass
1 torch
1 small bottle
1 tin lid
Water
Milk
Some pieces of cardboard
Smouldering string
Gummed tape

Light rays made visible! But aren't they always visible? No. In fact you might say that they are never visible. The source which emits them such as a candle, a lamp, the sun, is visible. Objects which are struck by the light rays and which reflect or disperse them are visible; but we cannot see the light rays themselves. The title of this experiment, then, is actually wrong. What it does mean is: making the paths of light rays visible by letting them strike suspended particles of smoke. For, as everyone surely knows, we can follow the paths of light rays through smoke or mist very precisely. With a smoke box of your own making, some very beautiful effects can be produced.

A strong shoebox will do very well. Cut a long rectangular piece out of the lid and replace it with a piece of glass, which can be held in place with adhesive tape. In one of the ends of the box cut out a square window. Paint the inside of the box with matt black paint. Finally cut some pieces of card which will fit tightly inside one end of the box and cover up the square window. In one of the cards cut a perfectly round hole about $\frac{1}{4}$ inch in diameter. You might be able to do this with a suitable cork-borer at school. In another card make three holes in a horizontal line and in a third make a lot of very small holes.

The room should be darkened for experiments with your smoke box. Place the torch about a yard, or less, from the square window, adjusting the distance so that the rays of light inside the box are parallel to the long sides. Now put into a corner of the box, on a small tin lid, something which smoulders and gives off smoke, such as a bit of rotten wood, a cigarette end or an old shoelace. Then put the lid of the box on. Now you will be able to see very clearly that light travels in straight lines.





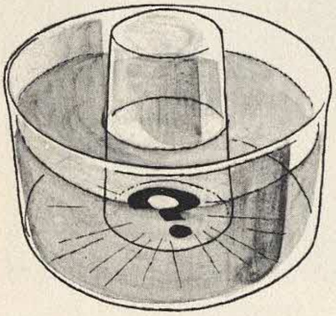
Optical phenomena such as reflection and refraction can be demonstrated very effectively with your smoke box. Towards the back of the box put a mirror at an angle of 45° and you will be able to observe how the beam of light is reflected so that the angle of reflection is equal to the angle of incidence (see the drawing). To make refraction visible put into the box a small bottle filled with water which has been made cloudy by the addition of a few drops of milk. You can follow quite easily the change in the direction of the light rays (that is, the refraction) resulting from the passage of the light from air into the glass and then the water, and back again from water, through the glass into the air.

By putting more mirrors or bottles into your box you can build up quite complicated systems of reflections and refractions.

Fix a lens over the round hole with some gummed tape and see how the parallel ray is changed into a cone; you can see the converging effect of a concave mirror by putting into your box a shaving mirror or, if you have not got one, a round soup spoon. For each of these experiments, use the three different cards and notice how extremely interesting and varied are the possibilities of your smoke box. Then perhaps you will feel like making yourself a much better box from wood.

Losing money

1 deep bowl
1 glass
1 coin
Some water



Now we are going to make your money disappear, but there will be no need to shout 'Stop thief!'. Actually we are not going to make your money really disappear, only seem to.

Fill a deep bowl with water and drop a coin into it. Put over the coin a fairly heavy drinking glass: push the glass straight down so that no air escapes from it. Now look through the side of the glass, and you see to your astonishment that the coin has gone, and no matter how you look, you cannot see it. Why?

It happens because from most viewpoints the rays of light from the coin are totally reflected at the boundary between the water and the glass, and so they do not reach your eye. The result is that you do not see the coin. However, if you look straight downwards from above the glass you will see your money all right—what a relief!

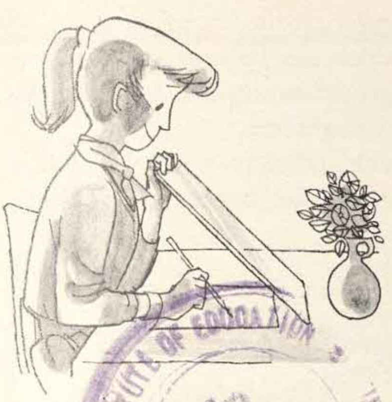
A handy drawing glass

1 oblong piece of glass
Drawing instruments

It is wonderful to draw, to put your ideas in line and colour on paper and to give visible form to what goes through your mind. It gives far more satisfaction than copying perfectly a print or a photo. But what can be great fun, too, is to draw from nature, though you need not try to copy all shapes absolutely exactly. If, however, you do want to copy something very accurately, for example, a vase, then an oblong piece of glass can be very handy. For the piece of glass makes a very good transparent mirror!

A *transparent* mirror? The drawing shows you how to set about it. Above the sheet of paper on which you are going to draw, hold the piece of glass at an angle. Look at the glass and you will see the vase—upside down—and, at the same time, the paper. The glass reflects like a mirror, but much more faintly, the rays of light from the vase to your eye, while at the same time the rays from the paper reach your eye through the glass. If you do not move the glass, and also hold your head still, you can draw the outline of the vase which you see in the glass almost as easily and accurately as when you trace something.

If you find it more convenient, or if it's better for the incident light, you can put the glass and the object that you want to draw on your left or on your right while you hold the glass at an angle. Perhaps you could contrive a small stand from wooden laths to hold the piece of glass at the correct angle to the table so that you do not need to hold it.



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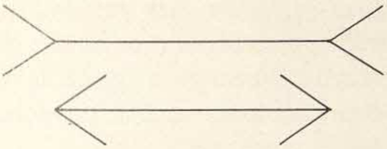
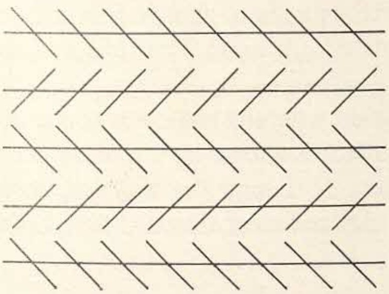
Don't believe your own eyes

'I shan't believe it until I've seen it with my own eyes,' we sometimes say—but can we trust our own eyes? The fact that we have seen something does not necessarily prove that it is true. The eyes can easily be deceived—for example:

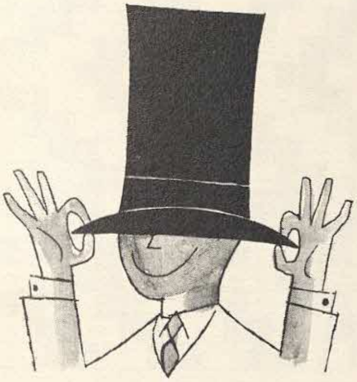
1. Which line is the longer? The upper one looks longer than the lower; but if you measure them you will find that they are both precisely the same length. The arrows cause this illusion.



2. These lines are not parallel, you say? Just you measure them. And these other lines, they get closer together, don't they? Don't be taken in, it's the sloping line across which lead the eyes astray.



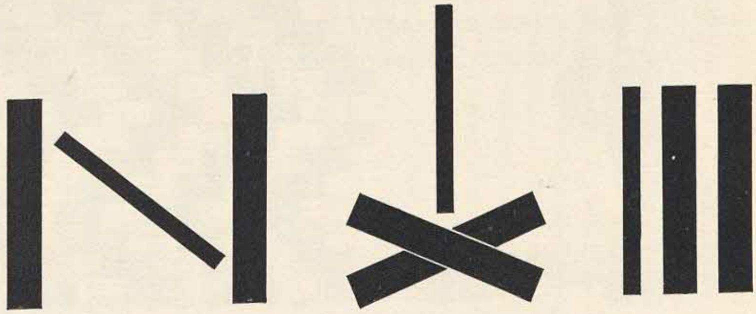
3. This tall hat looks much higher than it is wide. You need not try it on—just measure it!

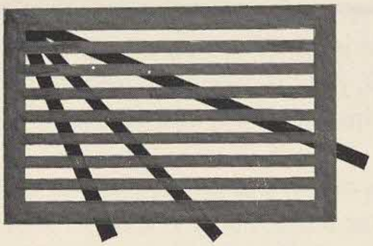


4. I expect you have often noticed that the moon looks much bigger when it is just above the horizon than when it is high in the sky. But this is only apparent, for we see the moon, apart from its phases, always the same size.

5. From white paper cut three strips of the same length, but make one of them half the width of the others. By laying the narrowest strip in three different ways alongside the other two, you can make it look as if it is shorter, as long and even longer.

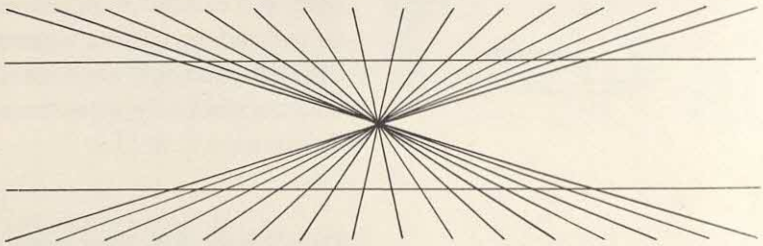
Paper
1 pair of scissors
1 pencil
1 pair of compasses
1 ruler

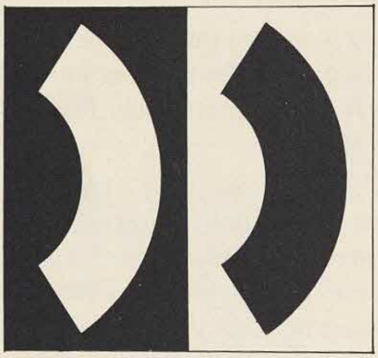




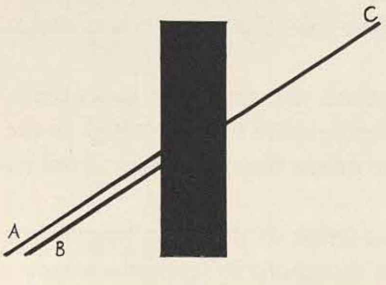
6. From a piece of paper cut out a grid as shown here and lay under it three strips of paper which can be rotated. The more you slant the strips the more you get the impression that the visible parts of them are not in the same straight line.

7. The eye can only judge with difficulty whether a line is straight or crooked. These lines are parallel, but they look bent.



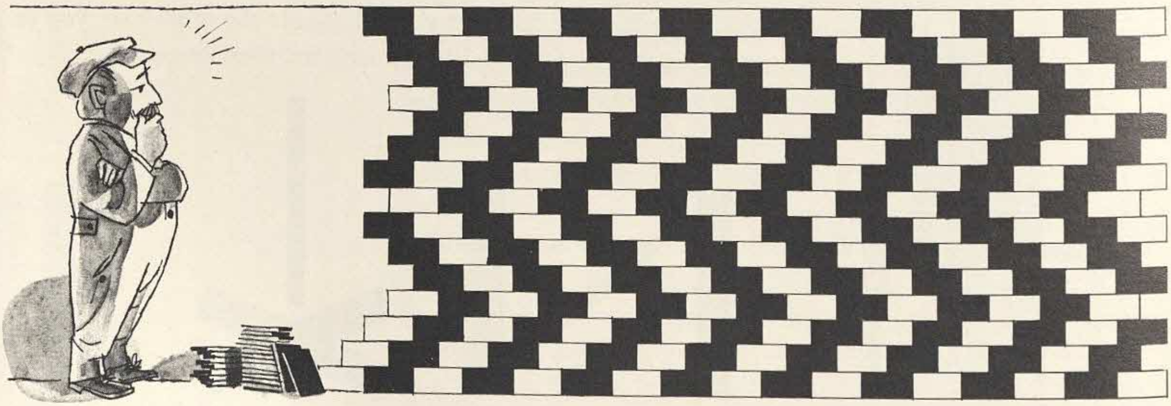


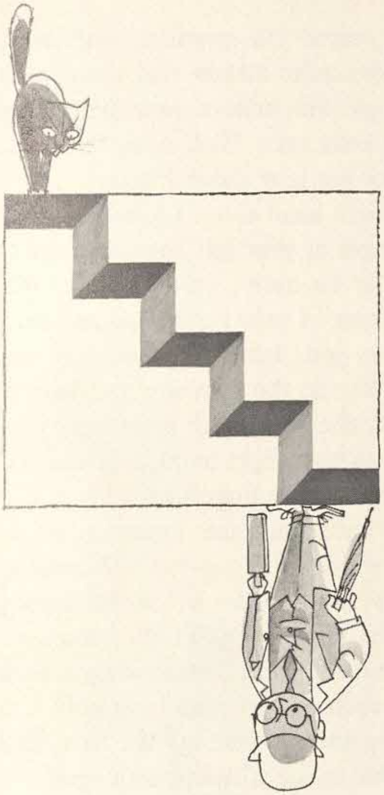
8. We are apt to see a light-coloured object larger than a dark one. So a pale-coloured car looks bigger than the same model painted black. It is much the same at sunset where, on the straight horizon, there seems to be a dent just where the sun is. In other words, the sun looks bigger than it really is just then. The strongly lit crescent moon looks as though it grips the dark part of the moon with its ash-grey light. A striking example of this irradiation of the eye is given in the accompanying drawings of segments of circles: the black on a white background looks smaller than the white on a black background. Measure these, too!



9. The eye is especially deceived by a sharp change from white to black. Look at this straight line AC. Wrong! The straight line is BC!

10. Another example of irradiation whereby the eye is confused by a sharp change from white to black is shown by a wall covered with light and dark tiles. It is just as though the wall has been very carelessly laid and as if the tiles are most uneven. But don't blame the workmen—blame your eyes.

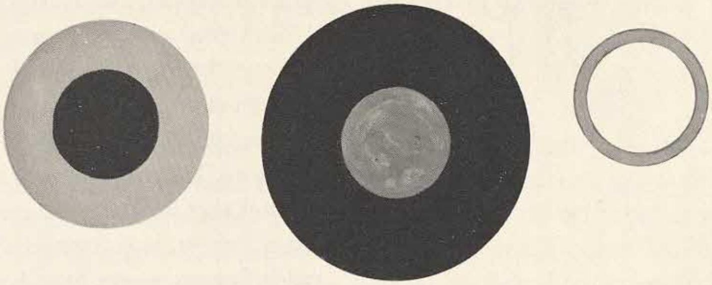


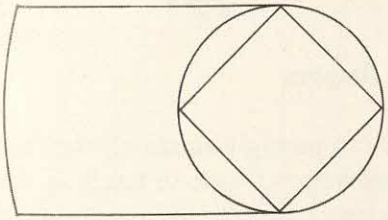


11. Our eyes are capable of seeing something in two different ways, as you can see from this drawing of the staircase. Turn the book upside down and you see a staircase again. But you can also see it as though you were looking at it from underneath.

12. Many optical illusions are the result of suggestion whereby we are deceived by our sense organs. But such mistaken experiences happen regularly. Here is a well-known example: read the following passage and count, as you go, the number of letters f that occur in it: 'The few fruits of this tree are the result of the stormy weather the last few days and of the insufficient scientific experience of the owner.' Read the sentence once only and remember how many times you came across the letter f.

13. Here are three circles with circles drawn inside them. Decide by eye alone which of the inner circles is the largest and which is the smallest, and then measure them!

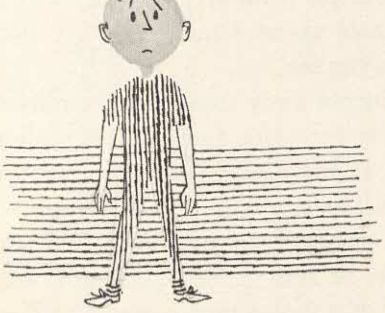




14. Because of the square it looks as though the circle is deformed and because of the slightly bent line at the end it is as though the two lines are not parallel.

15. If you stare for a while at moving water, for example, in a stream or river, and then suddenly stare at the ground, you will get the illusion that the ground is moving in the opposite direction. You can also see this remarkable illusion if you stare at a procession of people passing by.

16. Optical illusions can often be put to good uses. Ladies who would like to look slim often wear frocks with vertical stripes. Anyone who wears clothes with horizontal stripes looks plumper than he or she really is. If you want to make a low-ceilinged room look higher use a wall paper with vertical stripes.



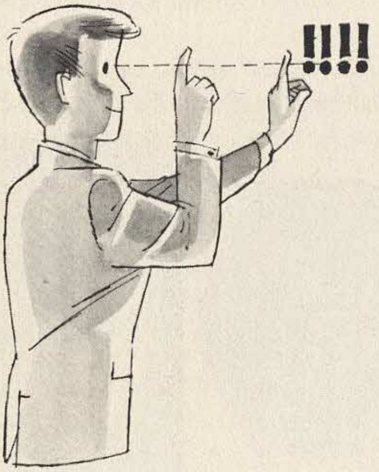
Finally, the actual number of letters f in the sentence is ten, but because the second and third words begin with an f many people pass over the f of 'of'.

Have you got four index fingers?

4 . . . no, 2 index fingers

A pretty silly question, eh? Of course you counted your index fingers last Saturday and you were quite certain that there were two. Now there are plenty of people who believe quite firmly that they have seen them with their own eyes. Well now, for those people here is the proof that man has four index fingers.

Hold the index finger of your right hand about 1 foot in front of your nose. Now hold the first finger of your left hand in front of your nose too, but about twice as far away, i.e. about two feet away. Look directly at the first finger of your right hand and then . . . you can see two first fingers on your left hand! Yes, you can! Try it again, it always works. Now do the opposite and look at the first finger of your left hand, the one which is farther away, and you can see two first fingers on your right hand, plus the first finger of the left hand, making three index fingers all told.



With your own eyes then, you have seen three index fingers on one and the same person. But if you work it out you will come to an even stranger conclusion. First you see two left index fingers. The second time two right index fingers. Didn't they teach us at school that two and two make four? Well, haven't we got here a proof that many an assertion, such as that men have only two index fingers, is completely wrong and misleading? We have four index fingers, as we have been able to see with our own eyes!

You have dozens of index fingers

1 ordinary mirror
1 old mirror
1 knife
1 index finger

By using a couple of mirrors you can multiply amazingly the four index fingers which you equipped yourself with so nicely in the previous experiment. You will need an old mirror with the protective covering of cardboard, leather or plastic removed from the back. This reveals the layer of red-brown paint. From the middle of this layer remove some of the paint very carefully with a knife or razor-blade so that a hole about a quarter of an inch square is left through which you can see.

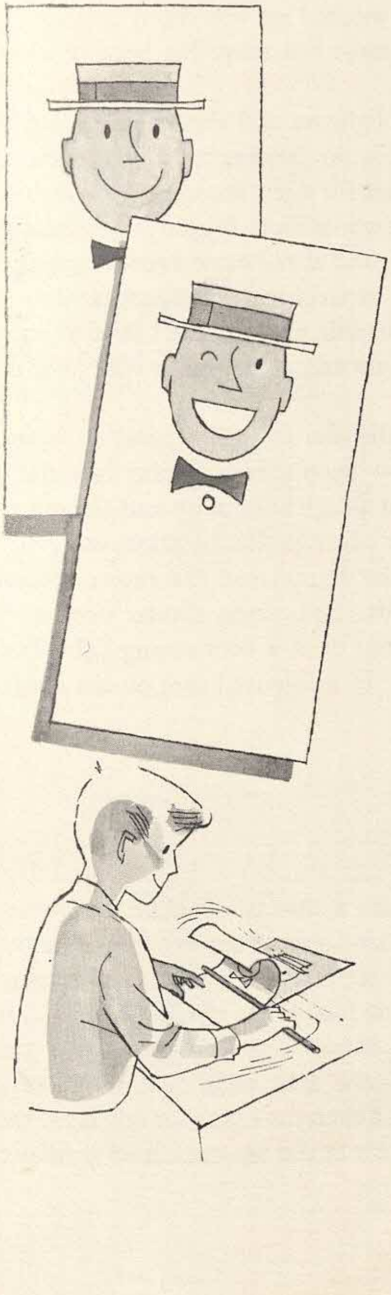
Now hold this mirror a few inches away from a larger mirror and parallel to it. Look through the little hole and hold your index finger between the two mirrors. If you have got the two mirrors parallel you will see an almost endless row of fingers—dozens. . . .

If the mirror is small enough not to cover your nose, and you turn the mirror slightly, you may be able to see dozens of noses. It is possible, too, with the aid of a larger mirror and a wall or dressing-table mirror, to have your whole head reflected so many times that it looks just as though there is a great row of yourself. Of course you will have to hold your head between the two mirrors.

Mr Wink

Paper
1 pair of scissors
1 pencil

The human eye is slow in the sense that light impressions remain fixed for a short time—a little less than a tenth of a second—with the result that impressions which rapidly follow one another cannot be observed separately. Hence, if a glowing cigarette end is whirled round in a darkened room it is not seen as a rapidly moving point of light but as a red circle. Electric lamps give fifty times a second alternately more and less light, but because of the slowness of the eye we do not notice it. A film consists simply of still pictures projected very quickly one after the other, which we observe as one moving picture because of this 'persistence' of vision. In television there is just a spot of light, moving as fast as lightning, which gives us the illusion of a complete picture full of movement.



The slowness of the eye gives us the opportunity to make a drawing of a face wink or grimace. Cut two pieces of paper each 4 inches by 8 inches, lay them exactly one over the other and draw a roguish man's face, pressing hard on the pencil point. Because the lines of the drawing of the face on the top sheet are pressed through on to the lower sheet you can make an exactly similar drawing on both sheets. The only difference is that on one of the drawings you show one eye closed in a wink.

Roll the top sheet of paper round a pencil. Now, if you take the pencil away and the paper is sufficiently springy, it rolls up again. Next, lay the rolled-up paper precisely on top of the other so that the two drawings coincide exactly. If you now stroke the pencil quickly up and down over the top sheet you will see in rapid succession the drawing with the open eye followed by the drawing with the closed eye, just as though the man is winking at you.

In the same way you can make the man open and close his mouth, you can have him blinking both eyes, you can give him ears which flap backwards and forwards, you could make his bow-tie or his eyebrows move. . . . Anyone with a bit of ingenuity can produce the funniest ideas.

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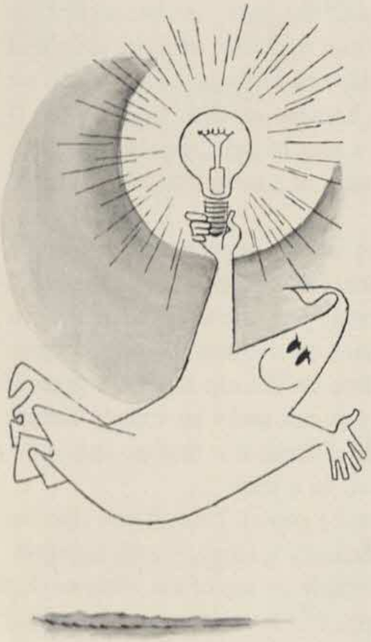
Let's make ghosts

1 well-darkened room
1 lamp

The following experiment requires a fair amount of patience, but you will be richly rewarded in the shape of something really ghostly. With your friends, relations or guests, sit round in a circle in a room which is so dark that even quite a few minutes after the light has been put out you can still hardly see your hand before your face. The company sits around one lamp which one person can switch on and off. While the lamp is out the group must sit for at least 5 minutes—preferably 10—in the complete darkness. You can help to pass the time by telling ghost stories. As the time approaches for the light to be switched on everybody must look straight towards the lamp, and must not move his head or eyes afterwards.

Then somebody switches the light on and almost immediately switches it off again, so that it is on for a second at the most. When the light is out again you see for a few seconds afterwards—and how wonderful it looks—the whole room brightly illuminated! Everything is so sharp and clear, and at the same time so ghostly, that you will never forget this experiment as long as you live. But remember—this experiment will only succeed if you stare steadily at the lamp while it is alight and do not move your head or eyes.

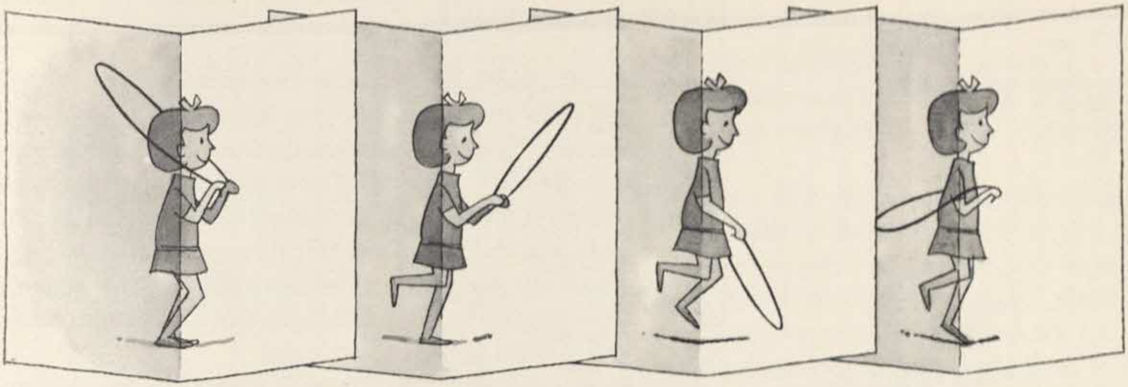


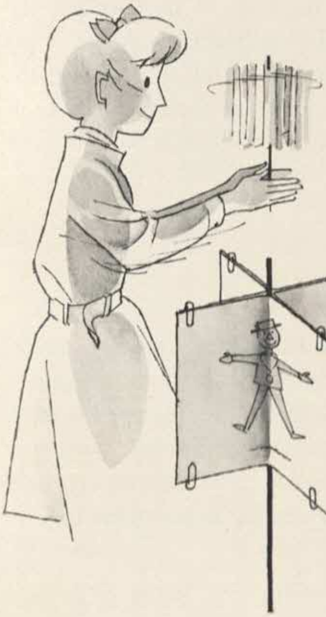
What you see immediately after the lamp has been on is the 'after-image'. Because you have been sitting in the dark for a long time, your eye has acquired a high sensitivity and the image of the room, in that short instant of strong illumination, has made such a strong impression on the retina that the retina retains it for several seconds afterwards. Something similar occurs if, by mischance, you look at the sun or at a very strong light. For quite some time afterwards you see a coloured spot on the image of whatever you are looking at.

Make a movie

White card
1 pair of scissors
1 pencil
Paper clips or paste
1 thin stick or paintbrush

In the cinema you see more than a thousand photos a minute, 1,440 to be exact. Because of the slowness of our eyes these photos give the impression of a moving picture. We can obtain something like this for ourselves by making on four pieces of white card, about the size of a postcard, four drawings representing, say, a girl skipping. Before you start to draw fold each card lengthways exactly through the middle, then flatten the cards out and lay them on top of each other. In the middle of the top card draw a picture

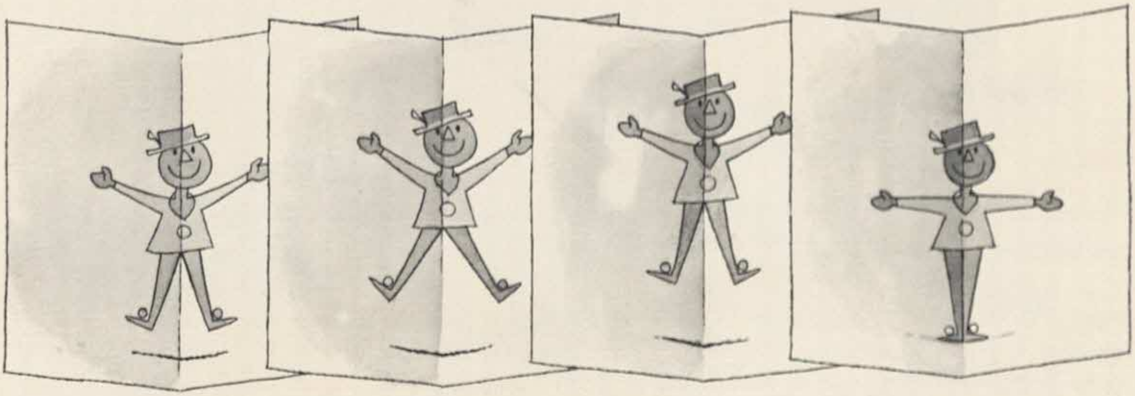




of a girl with her arms up and the rope in its highest position. Press hard with the pencil, and lay a thick newspaper under the cards so that your drawing is pressed through on to the underlying cards. On the other three cards draw three other positions of the girl and the rope—look at the picture.

Fold the cards again so that the two halves are perpendicular to one another and make a sort of mill, as shown in the picture. You can make this in different ways, by clipping the cards together with eight paper-clips or pasting them together. But you must fix them in such a way that a narrow space, like a tube, is left so that a thin stick such as a paintbrush will fit loosely inside. Now you will have a sort of mill which will spin round when you blow it, and as you watch you will see the girl moving . . . and skipping.

Of course you can draw all sorts of movements and figures: for example, vaulting, somersaulting, handsprings, swinging, cycling . . . oh, if you once begin making movies yourself you will get more and more fun out of it. Of course you can use both sides of the card.



A hole in your hand?

1 cardboard tube
2 hands

There's no need to be frightened by this experiment either, for you will not really make a hole in your hand. But you *will* see a hole in your hand big enough for a small mouse to creep through!

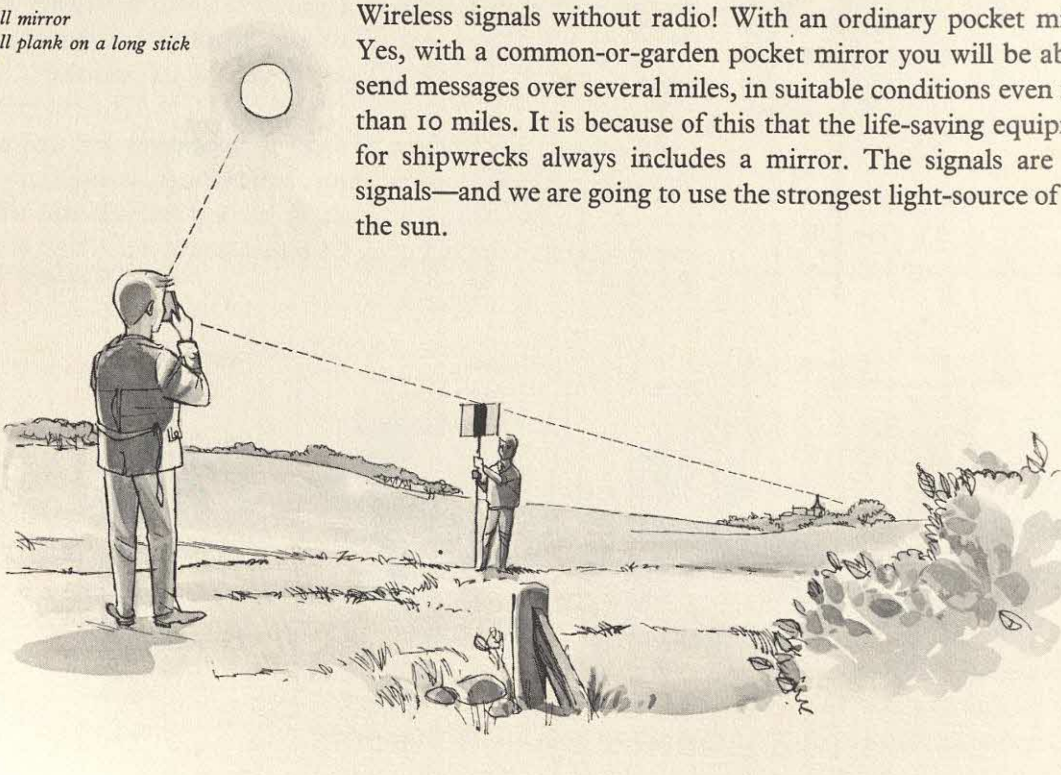
Take a cardboard tube or make yourself one by rolling up a piece of stiff paper and securing it with an elastic band. Hold the tube firmly in your right hand and look through it with your right eye. Hold your left hand in front of your open left eye, and you will see a hole right through the middle of your hand, a nice round hole but not a single drop of blood spilt!

Of course it is only an optical illusion, but even so a very interesting and instructive one. Our two eyes receive two images, but in the brain the two images are fused together so that we get the impression that we receive only one. In the brain, an image of the tube through which we see the background and an image of the left hand are combined, so that it seems just as though the hole in the tube is in your hand. So . . . a hole in your hand without pain or loss of blood.

Wireless signals

1 small mirror
1 small plank on a long stick
1 sun

Wireless signals without radio! With an ordinary pocket mirror! Yes, with a common-or-garden pocket mirror you will be able to send messages over several miles, in suitable conditions even more than 10 miles. It is because of this that the life-saving equipment for shipwrecks always includes a mirror. The signals are light signals—and we are going to use the strongest light-source of all—the sun.



THE MORSE ALPHABET

a	· —	n	— ·
b	— · · ·	o	— — —
c	— · — ·	p	· — — ·
d	— · ·	q	— — · —
e	·	r	· — ·
f	· · — ·	s	· · ·
g	— — ·	t	—
h	· · · ·	u	· · —
i	· ·	v	· · · —
j	· — — —	w	· — —
k	— · —	x	— · · —
l	· — · ·	y	— · — —
m	— —	z	— — · ·

1	· — — — —
2	· · — — —
3	· · · — —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— — · · ·
8	— — — · ·
9	— — — — ·
0	— — — — —
full stop	· · · · · ·
comma	· — · — · —
question mark	· · — — · ·

With a sharp knife scrape away from the back of the mirror some of the layer of silvering so that a small hole is left for you to see through. You are going to use the mirror to reflect the sun's rays towards the target. But how can you hold the mirror so that the rays fall exactly on the target?

You will need an assistant for this. He should have an oblong board fastened to a long stick—like a banner. Down the middle of the board make a broad black stripe. The stripe is your sight. Arrange that your friends, to whom you are going to signal, take up a position on a hilltop some miles away. Then ask your assistant to go and stand between 10 and 20 yards away from you and put yourself in such a position that the hilltop and the black stripe appear to be in a straight line. Now look through the hole in the mirror and adjust it until the reflected light makes a spot of light on the board right on the black line.

If now you make adjustments so that the lower edge of the beam of light touches the edge of the board by the black line while, at the same time, over the line, you can see your target, the top of the hill, your friends there will be able to observe the strong flashes from your mirror.

You can send the dots and dashes of the Morse alphabet in two ways, either by flicking the mirror up and down so that the reflected light either passes over the board or falls completely on it, visible as a round spot, or by your assistant lifting the board alternately up and down so the light is either stopped or let through.

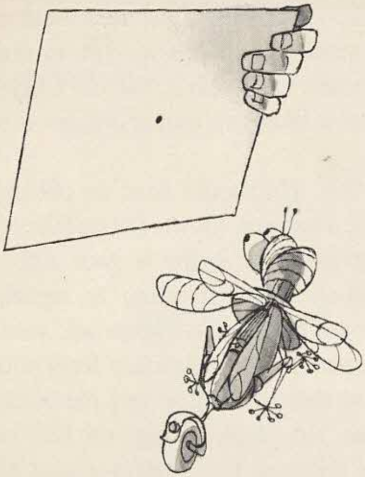
In your holidays you can make some very interesting experiments. The best is from one church tower to another. For then you will be high up, and a tower can be seen easily. A telescope will help in observing the signals. In this way, enormous distances can be covered—with an ordinary pocket mirror distances of more than 20 miles have been bridged! With a larger mirror and a telescope more than 60! Signalling with mirrors and sunlight—heliography—was once used a great deal in wartime. But when it rained, it rained complaints!

A magnifying glass . . . without glass

1 piece of card or stiff paper
1 pin

A magnifying glass without glass, that sounds as silly as a motorcycle without a motor. Yet such a magnifying glass is possible and you can easily make it yourself.

Through a piece of card, a postcard or a piece of stiff paper prick a hole with a pin. Now hold your eye close to the hole and look at some object through it. The object should be held about an



inch from the hole. It will appear to be very large. Of course, it must be strongly illuminated.

The hole cannot magnify in the same way that a lens or concave mirror does, but it enables you to place your eye very close to the object. With the normal eye you cannot see an object clearly and sharply if it is nearer than about an inch. The lens of the eye just cannot manage it. But by putting a diaphragm in front, with a far smaller hole in it than the pupil of the eye, the depth of focus, which determines the clarity with which you see, is increased considerably. It is just the same with a camera. The smaller the diaphragm, i.e. the lens opening, the greater is the depth of focus.

The smaller the hole is, the nearer you can hold the object. Look at an insect, or the pistil and anthers of a flower, with your glassless microscope. You will be amazed at all there is to see.

Make a microscope

1 piece of tin or aluminium foil
1 drop of water
1 fine nail or pin

One of the most famous Dutchmen of the seventeenth century was Anthony van Leeuwenhoek who, even though he had no scientific training, made the best microscopes in the world and made some of the most important discoveries. He was the first man to see bacteria. Because of these discoveries he was made a member of the Royal Society of London. His microscopes were simplicity itself; they consisted of little more than a brass plate, an adjusting screw and a tiny lens in the form of a perfectly round glass bead. We are going to make a microscope like that with a very strong lens. But in order to do it we are going to use not glass . . . but water!

It is quite simple and the result will really astonish you. Take a piece of thin tinplate, or a piece of stiff aluminium foil, and with a nail (not one like a tin-tack) make a perfectly round hole. Now hold the piece of metal with the hole in perfectly horizontal and very carefully let a small drop of water fall on the hole from a straw or a water-colour brush. The drop will stay in the hole like a tiny lens. Look through it at a piece of cotton material held very close beneath it. Instead of the material you can use sugar grains or salt crystals on a dark background. Have a look at a dead insect or anything else that you think is worth examination—it will be greatly magnified.

Make sure that any object which you want to look at through your water-drop microscope is very well illuminated. Try the effects of holes of different sizes and different water-drops—the curvature of the drop determines the number of times that your microscope magnifies. The distance between the drop and the

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object that you are observing is only very small—in most instances hardly an eighth of an inch.

With your own microscope you will be able to discover the most beautiful things, for example, that the crystals of fine table salt are all perfect cubes.

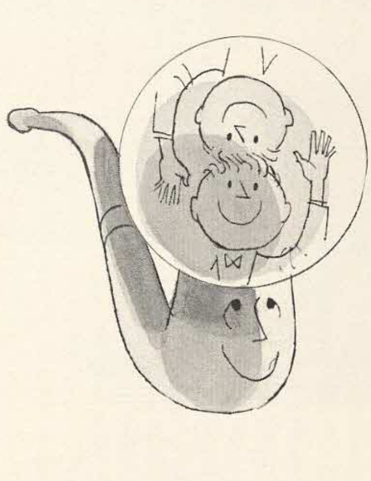
See yourself right way up and upside down at the same time

Soapsuds
1 plastic or clay pipe
1 Christmas Tree bauble

We often hang on our Christmas trees those lovely balls of silvered glass. One of those balls makes a very strongly curved mirror in which you can see an entire room. It is even better if you look at the ball through a magnifying glass.

But you do not look very beautiful if you look at yourself in one of these balls. Hold your nose close to the ball, or stick your tongue out, and your nose or tongue is monstrously enlarged. Take a ball out of doors and notice how the whole sky with all the clouds appears in the one ball.

A ball of this kind gives an upright, diminished image of yourself. If a hole is made in the ball, or it gets broken, you will see in the concave inside of the ball a similar diminished image, but this time inverted. Now would it be possible to combine a concave and a convex mirror in such a way that, at the same time, you could see an upright and an inverted image of yourself? Yes, it is possible if you use transparent mirrors, and they can be found in . . . soap bubbles!



You can make strong soap bubbles by adding to the soap solution a dash of glycerine or a little sugar. A bubble made with this solution is wonderfully strong even though the skin of the bubble is only a few thousandths of an inch thick. Find some quiet, draught-free place and make a nice big bubble, either with a pipe or by dipping into the soap-solution a ring of wire about one inch diameter on a handle of the same wire. You may be able to let the bubble fall on to a soft cushion so that it will stay there. On the other hand you can make it remain on the end of the pipe by closing the open end with your finger. Now, if you look carefully, with the right lighting conditions, into the bubble you will see yourself upright in the convex near side of the bubble and upside down in the concave far side of the bubble. So there you are right way up and upside down at the same time, a feat which the finest acrobat in the world cannot beat.

Pin and double-pin

1 piece of thin card or stiff paper
1 pin

Come, let's give an ordinary pin a double. We can do this without getting more pins. There's no skill in that. No, with just one pin alone we are going to make a double. Yes, two, three, as you will!

Prick with the pin two small holes very close together in the piece of card or paper. The holes must not be more than an eighth of an inch apart. Now, with one eye look through the two holes, and hold the pin about an inch away on the other side. You will see that the pin is no longer alone, but has gained a double.

Prick another hole close to the first two so that a triangle is made. If you look through these holes you will see three pins. Prick a few more holes and then see what happens. Try the effect of turning the card round slowly while you are looking through the holes. You will probably find that there is a certain position where you can see the 'doubles' most clearly.

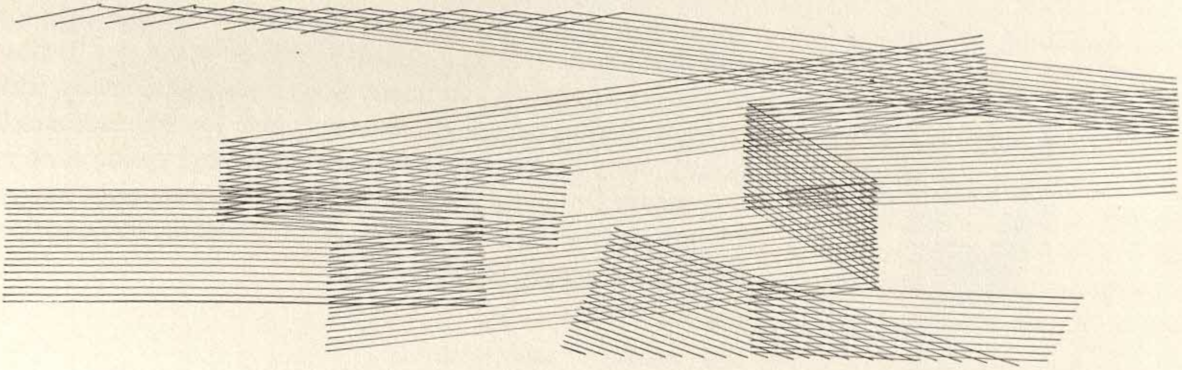
This is yet another example of an optical illusion: with one eye only you can see several images of one pin at the same time. But it is clear that because of the different holes, which are so very much smaller than the pupil of your eye, different images of the pin are formed on the retina of the eye.

Moirés

Pieces of gauze
2 combs

No doubt you have noticed what wonderful patterns appear when two pieces of gauze (for instance, the gauze of a mosquito net and the gauze of tulle curtains), or the teeth of two combs, are allowed to lie over one another. By letting them rotate, one over the other, ever more patterns appear.

Such moirés, as these patterns are called, can be made with almost anything in which regular patterns of holes or slots are present. Examples are metal gauze, net window curtain material,



bandage, discarded nylon stockings, the teeth of combs, even the bars of chairs or hedges. Try to obtain some pieces of perforated zinc or metal gauze, lay one on top of another and hold them up to the light. Patterns appear immediately. Turn and move them slightly, one over the other—many more patterns appear, blocks, ovals, squares, diamonds and dozens of other wonderful figures. The strangest thing is that they appear as if by magic—suddenly and mysteriously. . . .

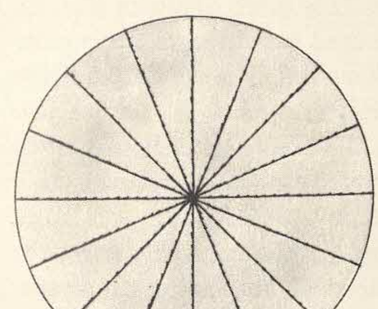
Also, if you walk alongside two parallel fences with upright posts, you will be able to observe similar patterns. It is just as though the light appears as light and dark waves. The explanation of all these phenomena is not so simple—they can best be compared with the interference, or beats, which occur with two notes having only a small difference of frequency.

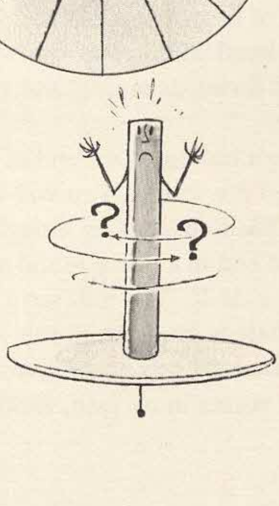
Make a stroboscopic top

1 pin
White card
1 short stick
Paintbrush, pen or pencil
Ink
Pair of scissors

A stroboscopic top . . . that sounds mysterious, doesn't it? And so it is.

But let's make one first. You will need a pin, a short round stick and a disc of white card about 2 inches in diameter. On the white card you must make stripes as shown in the drawing. First draw a cross with pencil, ink or paint, then a second cross at an angle to the first, so that its arms are exactly in the middle of the spaces between the arms of the first one. Do this twice more so that in the end you have sixteen stripes.





With some glue fasten the disc of card to the stick and then push the pin in far enough to enable the top to spin freely. If you look at your top in daylight as it spins you will notice nothing unusual. But switch the light on one evening, then spin your top, and you will see the most remarkable sight; as the top spins the stripes will seem to be turning round the opposite way, stopping or going round very slowly—quite independently of the speed of the top. This makes it seem as though the whole top is spinning in the opposite direction, stopping or turning slowly. But this is merely an illusion. How does it happen?

The electric light goes out 100 times a second, but our eyes cannot see this rapid going off and on because the impression of the light lasts for $\frac{1}{10}$ of a second. But when the spinning disc with stripes appears to stand still, each stripe has taken the place of the next one during the time that the light was out. So you do not see the movement of the stripe, with the result that the stripes seem to stand still. If the disc spins a little slower, it appears to go backwards—a little faster gives the impression that it is turning quite slowly in the same direction as the top. A stroboscopic disc like this is used to check the speed of a gramophone turntable. Some records even have the necessary stripes on the label. If they appear stationary under electric light when the record is turning, then the speed is exactly right.

Stroboscopic marvels

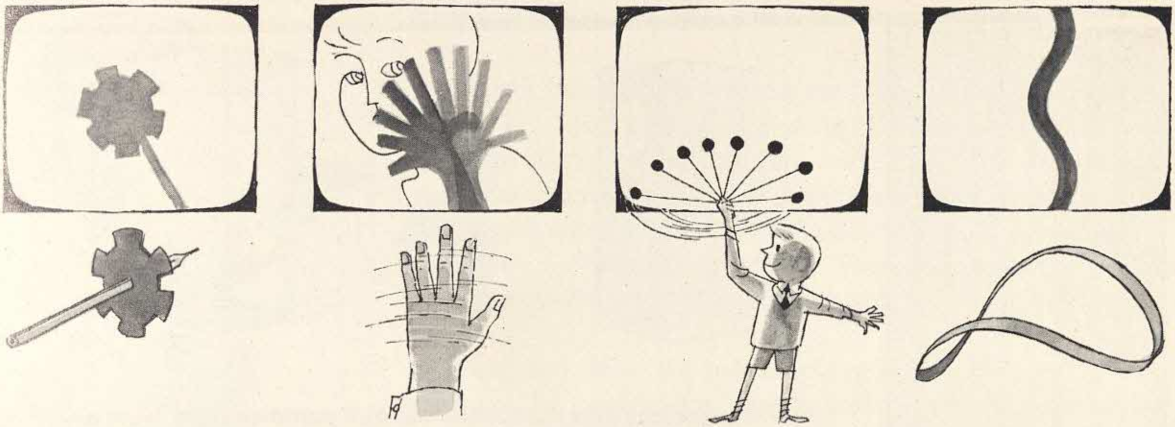
1 television set
1 piece of elastic
1 piece of card
1 pencil
1 piece of thread
1 button
1 ball of paper
1 curved piece of wood
1 length of cord

A great deal of use is made in industry and in scientific research of the electronic stroboscope, which gives out a pre-arranged number of bright flashes per second. With the instrument it is possible to make all sorts of motion appear stationary and so, for example, it is possible to watch the behaviour of a fast turning propeller in water, or in air.

We can make some interesting stroboscopic phenomena visible by using the television set. Increase the brightness of the picture and reduce the contrast so that you get a milk-white area on the screen. You can consider the light which comes from the screen as a certain number of light flashes every second. Out of card cut the toothed wheel as shown in the drawing, bore a hole in the centre, push a pencil through to make an axle and then spin the wheel round in front of the screen. It is quite simple to increase or decrease the speed of the wheel until you discover a particular speed at which it appears to be standing still. The same explanation as we gave for the previous experiment applies to this one too. You can see the same sort of thing in a film or on television when the wheels of vehicles seem to be spinning in the opposite direction to the motion of the cars, bikes, etc.

Spread out the fingers of one hand and then slowly move the hand backwards and forwards horizontally in front of the screen. You will be amazed at the number of fingers you can see! You do not need to move the whole of your hand. Hold your wrist still and just move your hand backwards and forwards rapidly and you will see one hand with dozens of fingers.

Make a simple pendulum by tying a button on the end of a piece of thread and let it swing in front of the screen. You will see this one thread quite sharp in several positions just as though there were several threads. Fasten the free end in a noose round a round pencil and swing the pendulum in a circle. You will see a sort of crown of buttons, and dozens of threads like rays in this moving circle. Throw a ball of paper horizontally across the front of the screen and you will see it as single points in its path, looking just



as though there were two, three or four paper balls hanging still in the air.

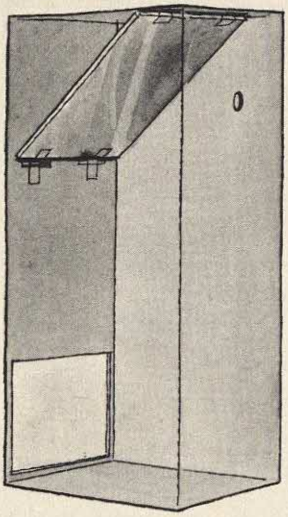
The way in which a cord vibrates can be shown very well by your TV-stroboscope. Stretch across the screen, horizontally, a piece of elastic and pluck it. Do it several times, also try tightening or loosening it. This will enable you to hear different notes and to see the waveform of the cord. With some pitches of note you will see the elastic strongly curved, but stationary, while in fact it is vibrating backwards and forwards many dozens of times a second. If you have a violin or guitar let the light from the screen fall on the strings while you bow or pluck them. Unusually interesting. You can stroke your elastic cord too with a simple kind of bow made from a curved bit of wood which has a piece of rough cord stretched across its ends. Then you can make your strange waveforms last for a longer time.

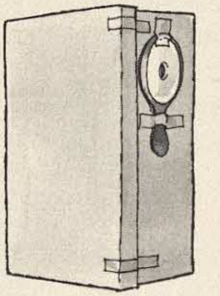
Make yourself a viewer

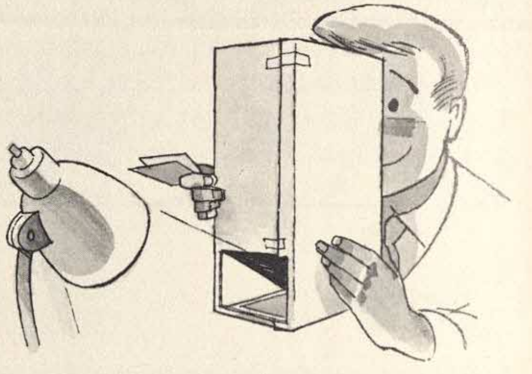
1 box
Gummed tape
1 mirror
1 magnifying glass
1 pair of scissors

A viewer is just the thing for looking at photographs. Your holiday snaps look so much bigger and better. Moreover, they look as though they are in 3D. This happens chiefly because they are surrounded by a dark frame. Why not make a viewer for yourself?

You need a suitable box, for example, a small shoe box. Make the inside black with paint or indian ink, or by lining it with black paper. Cut a rectangular window in the box and a round hole in the opposite side, as shown in the drawing. The round hole should not be more than $\frac{3}{4}$ inch in diameter. Almost any type of lens will do provided that you can see clearly an object that is between 8 inches and 10 inches away. The cheapest and most suitable lenses are the plastic magnifying glasses which are obtainable in so many shops.







Fix the lens over the round hole with gummed tape. Now you must fix a mirror into the box, as the drawing shows, at an angle of 45°. With luck you may already have a piece of mirror exactly the right size. Stick a piece of card into the box at an angle of 45° and then glue the mirror to it or fasten it with gummed tape. Stand the box upright, and lay a photograph on the bottom, making sure that it is well illuminated either by daylight or by a lamp. Look through the lens and you should see a brilliant, enlarged picture, full of depth and more beautiful than before.

On the other hand it may be that the picture is not perfect. Perhaps the mirror is not quite at the correct angle. You may have to adjust your viewer a little, but there is no doubt that in the end it will give you a very great deal of pleasure.

A magnificent illusion!

2 fingers

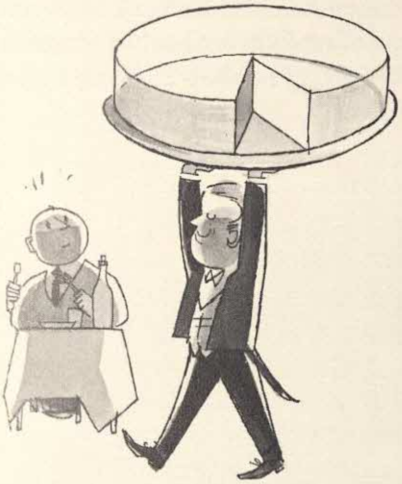
Hold the first fingers of each hand horizontally tip to tip about five inches in front of your eyes, and look at something in the distance beyond them. Do not look directly at the fingers. Now separate the tips slowly by about half an inch while you continue to stare at the distance. What do you see? There in the foreground, between your two fingers, is a strange floating object with a fingernail at each end. An unattached body, the shape of a little sausage, looking very much like a finger. And no wonder, for it is the ends of your fingers fused together that you are looking at.

What is the cause of this strange illusion? It is due to your eyes being focused on the object in the distance with the result that you see near objects such as your two fingers double, one with each eye. Now you get an overlapping of images—one of the images of the right finger overlaps one of the images of the left finger, producing that strange little sausage with fingernails at the ends which floats in the air like a flying saucer.

And yet another optical illusion

The Third Book of Experiments

For this experiment you will not need anything more than this copy of *The Third Book of Experiments*. Look at this picture. You are being offered a cake. One slice has already been cut out. Do you know where the piece is? If you really want to know, turn the book upside down so that you see the drawing upside down too . . . and there is the missing piece of cake! That missing piece suddenly looks like a solid piece of cake just asking you to put your teeth into it.



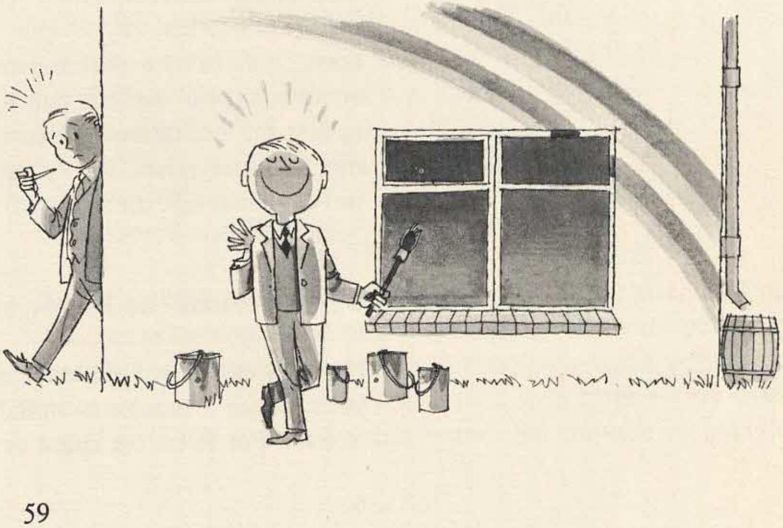
How's that? Why the sudden change? The eyes, acting like miniature TV cameras, send signals to the brain which interprets them in the most obvious way, the way we are most used to. We see the upright picture of the cake in the way in which we usually see a cake with a piece cut out, but when it is inverted we see a cake from a most unusual point of view and the brain interprets the image quite differently. Now the point of the cake appears to be nearer to us and what was drawn as a gap in the cake appears to be a solid and inviting piece. Eat up!

Let's make a rainbow

1 glass of water
1 sun
1 window sill
1 large sheet of white paper
1 garden spray or hose

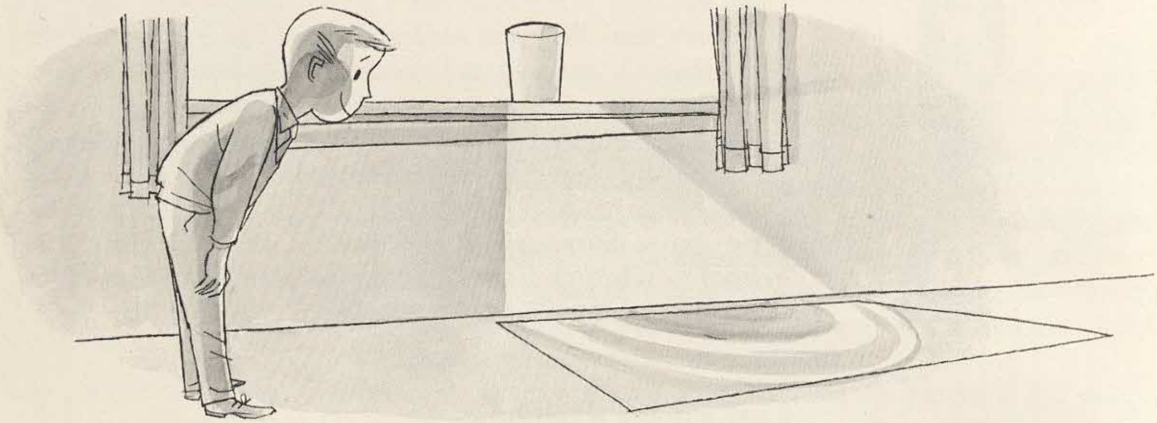
Quite the simplest way to make a rainbow is to make a real rainbow with artificial rain produced by a garden spray. It works best when the sun is low in the sky, in the early morning or late afternoon or evening. The spray must play in strong sunlight and the rainbow will only be visible against a dark background such as houses or trees in shadow.

At some great waterfalls, where countless millions of waterdrops



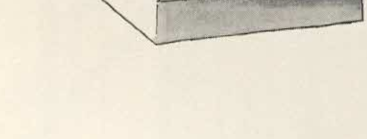
are floating in the air, you simply cannot escape from rainbows. I remember a visit to Niagara Falls where, at certain places, the rainbows seemed to stick with me like faithful puppies.

You can produce a rainbow in your lounge, too, simply by putting a glass of water on the window sill just inside the room. As you can see in the picture, the rays of sunlight are bent by the glass oɪ water in such a way that a very pretty rainbow is formed on a piece of white paper laid on the floor.



Yet another rainbow!

1 sun
1 dish of water
1 small mirror



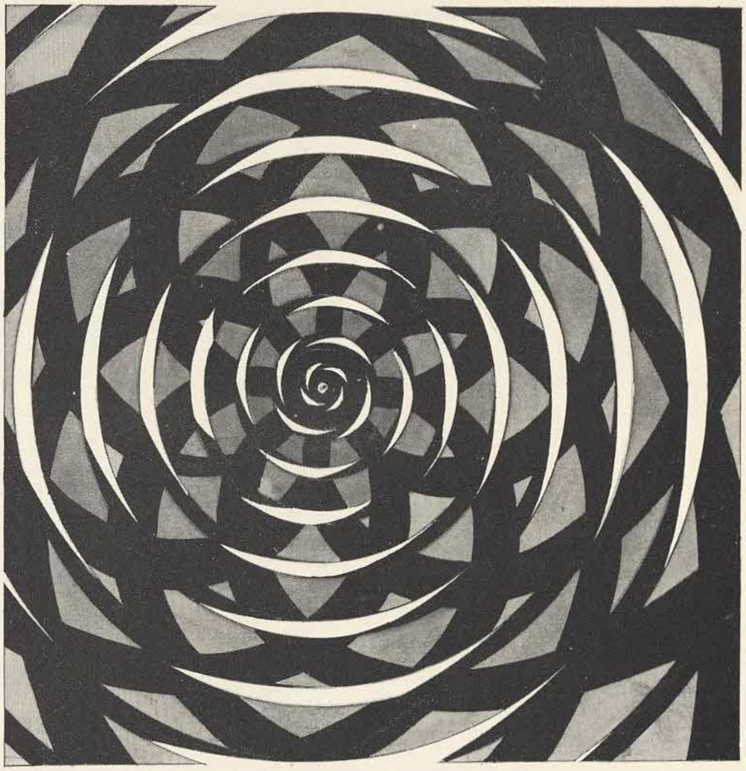
The most usual way of demonstrating the mixture of colours which we call white light is by using a prism. But it is not always easy to obtain one. The bevelled edge of a thick mirror will also break up a beam of white light into its constituent colours and project a beautiful spectrum on to the ceiling or a sheet of white paper—a rainbow in miniature. . . .

Here is another way to split up white light: against the side of a dish of water lay a small mirror and then place the dish in such a way that a ray of sunlight falls upon it. The mirror reflects the ray against the ceiling and because it is passing through what is in effect a water prism, the colour separation is brought about and you get a magnificent spectrum on the ceiling.

Do you know the Fraser-spiral?

White insulated wire
Black insulated wire

Have you ever heard of the Fraser-spiral? Well, here it is drawn for you. Rather a handsome spiral, eh? But who's talking about a 'spiral'? For it isn't a spiral at all. Those are concentric circles



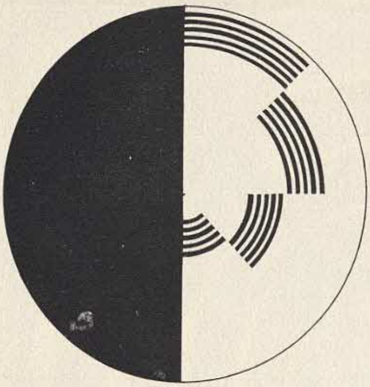
consisting of interlaced white and black circles. Because of these and because of the background of gradually increasing squares, we get the illusion of a spiral where, in fact, there are only concentric circles.

If you twist together black and white insulated wire, forming it into different shapes—not only concentric circles but other shapes, too—and then lay them on contrasting backgrounds such as a draught board, you will find you have some bizarre patterns. They are known as 'twisted cord illusions'. How this type of optical illusion occurs is not very well understood. There are all sorts of conflicting theories, but none of them gives a fully convincing explanation.

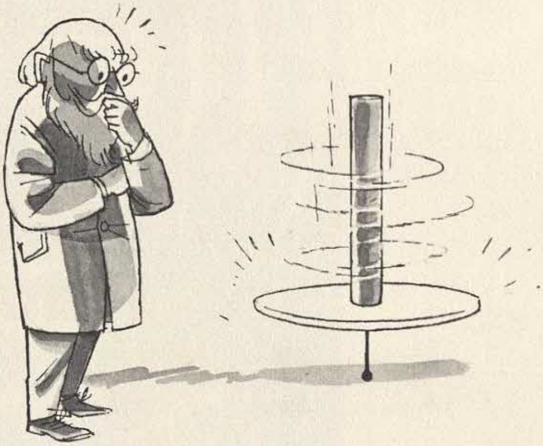
Science cannot explain this—can you?

1 piece of white card
1 pair of compasses
1 pair of scissors
1 pen
1 paintbrush
Indian ink or black paint
1 thin stick

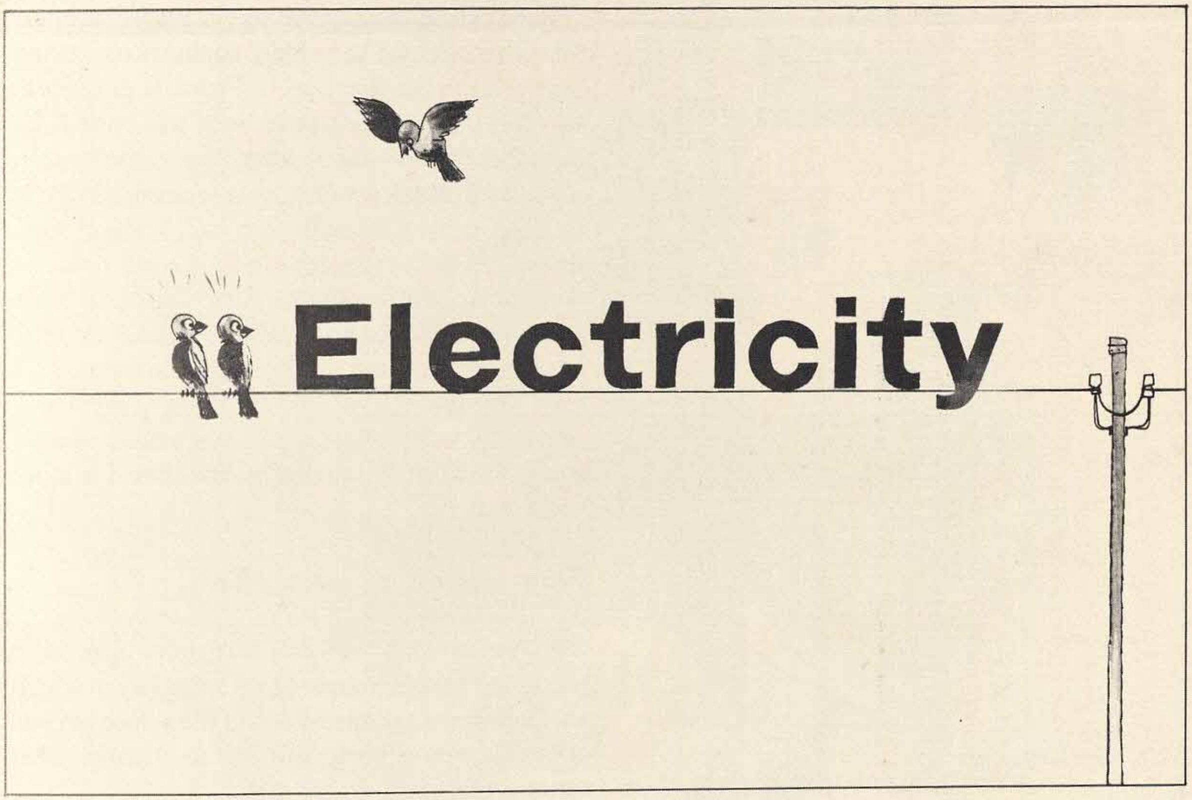
Scientists have been able to wrest many of Nature's secrets from her, but every now and then they come up against some phenomenon that they just cannot explain. Among them is the well-known disc invented by Fetchner. You draw it with black ink on white card, cut it out and push a thin round stick through the middle.



Now make the disc rotate at high speed. You could fix one end of the stick in the chuck of a hand drill, or spin it like a top. Now you see concentric circles, no longer black but coloured. Reverse the direction of the spinning and other colours appear. To this day it is a mystery to scientists why the disc, painted pure black and white should appear coloured. But perhaps you will be able to find the answer? Think very hard about it. A wonderful chance to become famous. . . .



Electricity



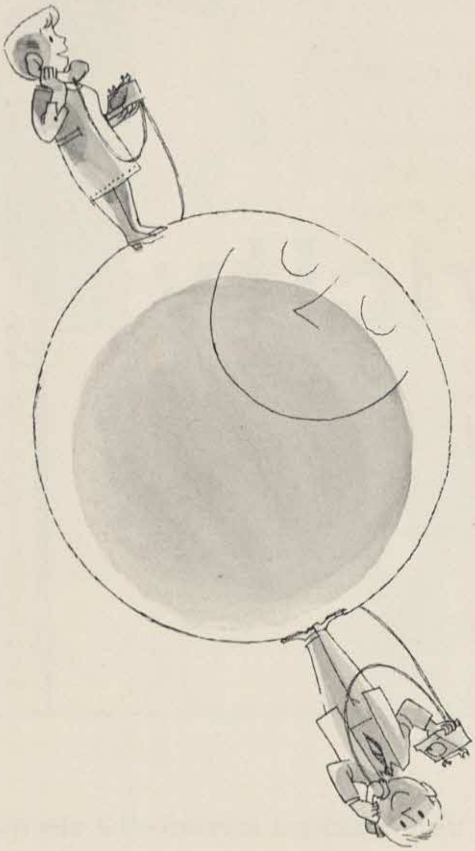
Your obedient servant—the electron

An electric current consists of a stream of electrons which are so small and light that 1,000,000,000,000,000,000,000,000 of them together weigh barely one milligramme. But you would soon appreciate the might of this tiny particle if, all of a sudden, there were no more electricity! Then you would sit up! Imagine that it is winter. You come home from school in the late afternoon—it is beginning to get dark and you put your hand out to switch the light on—but the house stays dark. And it is dark outside too, for the street lights are not on. You cannot listen to the radio or watch television, for they do not work. If you cook by electricity, potatoes, vegetables and meat cannot be prepared so you only get a cold meal. An unpleasant prospect, don't you think? And that is only the beginning of your troubles.

If there was absolutely no more electricity, no more electric trains would run. There wouldn't even be any motor cars. Cars, it is true, generate their own electricity, but we are supposing that electricity has disappeared altogether. Just imagine: machines no longer turn in the factories and so nothing can be manufactured. The telephone does not work any more, so if someone is taken ill you cannot ring for the doctor. If there is a fire, the fire brigade cannot be called.

With factories closed and transport paralysed, the shops are soon sold out, the fires and central heating go cold and soon we feel the pinch of hunger. Cold, hunger and darkness . . . and then a terrible stillness descends upon our bustling towns—the silence of the grave.

A ghastly prospect! How fortunate we are that



in fact the electrons never go on strike and that electricity is ready to serve us day and night.

When the electrons move through copper wires and other metal conductors we speak of electricity; when they pass through vacuum tubes ('valves') or gas-filled tubes fitted with two or more metal electrodes, or through what are called 'semi-conductors' (such as the 'transistors', which are now so widely used in radios), we speak of electronics. Electricity brought the electric motor to mankind—just count how many electric motors there are in your house; in the vacuum cleaner, washing machine, record player, food mixer, spin-dryer, electric drill, hair-dryer and other household appliances. And amongst the other benefits of electricity are good lighting, heating at the touch of a switch, and the telephone.

But electronics has given us even more wonderful things. One of the oldest applications, dating from 1895, is the X-ray tube. That it is possible to see right through the human body still borders on the unbelievable. And it's even more unbelievable, if you really think about it, that someone sitting in England or in America can speak, without even raising his voice, to someone on the other side of the world, in Australia or New Zealand. From Jakarta in Indonesia I once telephoned my wife in Amsterdam, and during the conversation I tried to imagine how the vibrations of my voice, carried by radio waves at 186,000 miles a second were covering the 10,000 miles—but I simply could not.

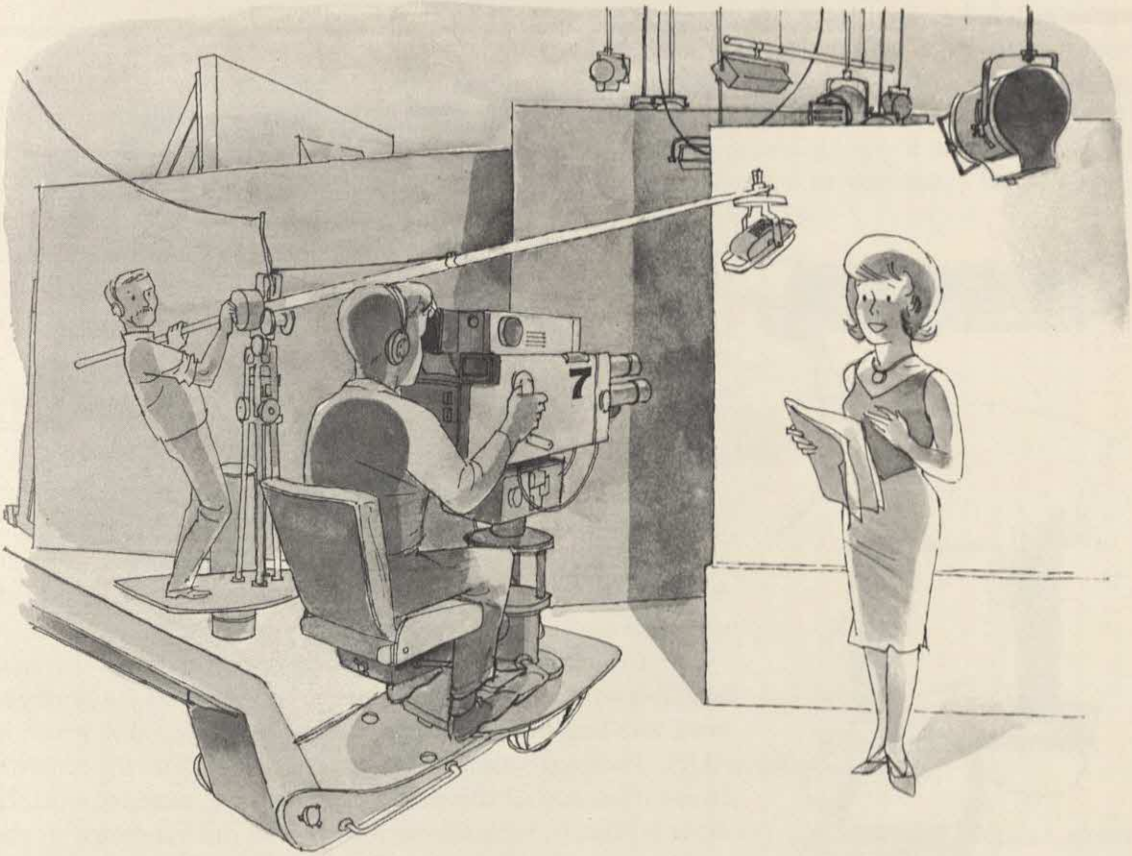
From 'vision' to television

Yet the wonders of the way in which radio works are simple compared with the way in which the pictures are conjured up on the screens of our television sets at home. Just try to visualise what takes place. . . .

An attractive young girl stands in the television studio under the glare of powerful lamps. Accompanied by a band, she sings in front of a microphone and performs before the three television cameras with their red and green signal lamps . . . a girl who has quite an effect on us because of her soft, sweet voice, her pretty face and her lovely complexion . . . truly a 'vision', in fact. . . .

On the other hand, the sober technical details: the cameramen controlling their electronic eyes, which can be moved in all directions without a sound; the picture and sound technicians behind sound-proof glass windows, and the stage manager giving his instructions by telephone . . . 'Camera 3—close-up!'

Then the system of lenses of Camera 3 focuses a tiny image of the girl on to a transparent screen coated with a photo-electric material. This screen emits electrons when light falls on it, and so it becomes positively charged. An electron beam sweeps across it with lightning speed, and as the



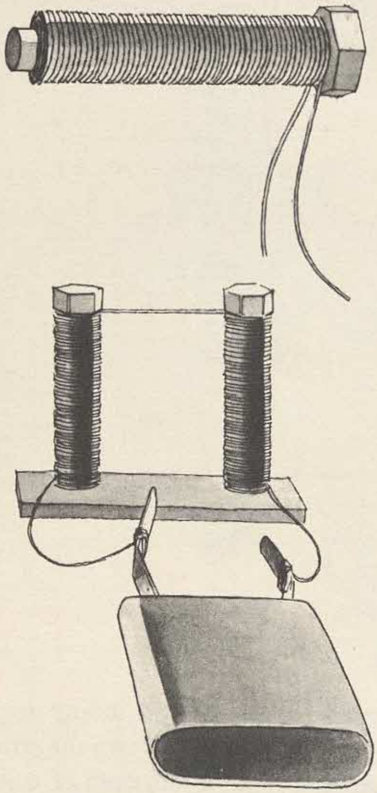
beam returns to its source at the bottom of the tube, it carries back whatever charges it has found on the screen. This information, the video-signal, is fed into amplifiers: and, within the glass walls of electron tubes (or 'valves'), they grow much stronger. Then they pass, mixed with all sorts of other signals, into the realm of the transmitter. Here the electrons are led a frantic dance through coils and capacitors, along treacherous, twisting paths and over obstacles, until in their frenzied rage they can find no way of escape except up the aerial mast. Up there, capering madly, they generate rapidly alternating electric and magnetic fields.

The waves which are set up are radio waves and they carry—in the form of fine, rhythmic vibrations—a jumbled-up picture of the girl. Very soon they strike a receiving aerial, and induce in it small oscillating electric currents. Down the aerial lead flow the currents, into a labyrinth of coils, capacitors and electron tubes. From these they emerge greatly amplified, and rush inside a cathode ray tube, where they cause a beam of electrons to sweep over the back of the picture screen in exactly the same way as the electron beam is sweeping over the photo-electric screen in the camera. The picture screen is coated with a chemical material which gives out light when electrons collide with it . . . and the miracle happens! Thanks to the laziness of our eye and the after-glow from the screen, we see a swift succession of points of light as a complete picture of that radiant young girl's face.

Switch on and off

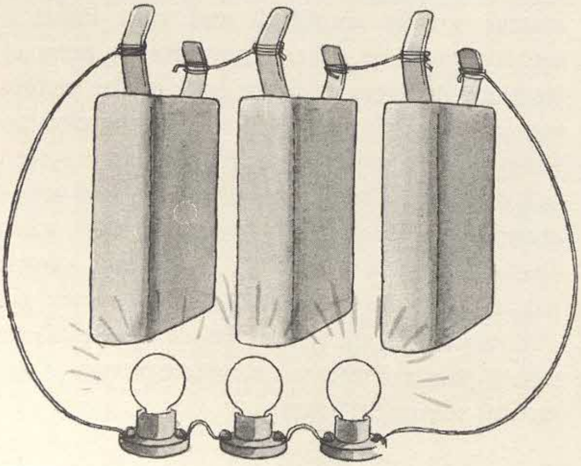
Thin insulated wire
1 iron bolt
Lamps
Lampholders
Switches

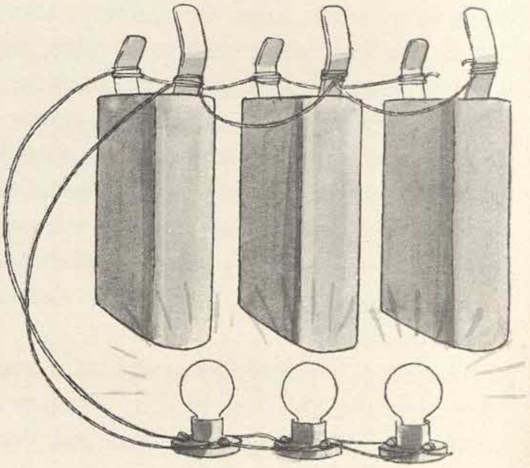
Before we start switching we are going to make an electromagnet. To do this you will need an iron bolt, a very stout nail or an iron rod or bar. A bolt will be best, and you should be able to get a suitable one from a good ironmonger. Wind round your piece of iron, very closely and tightly, about 20 yards of thin insulated wire, layer on layer. When you have done it you will have an excellent electromagnet which you will be able to use for all sorts of purposes—for example, a buzzer (see the next experiment) or an electromagnetic crane. You can make an even stronger electromagnet by screwing two such iron bolts into a bar of iron and connecting the windings together so that you have a U-shaped electromagnet.



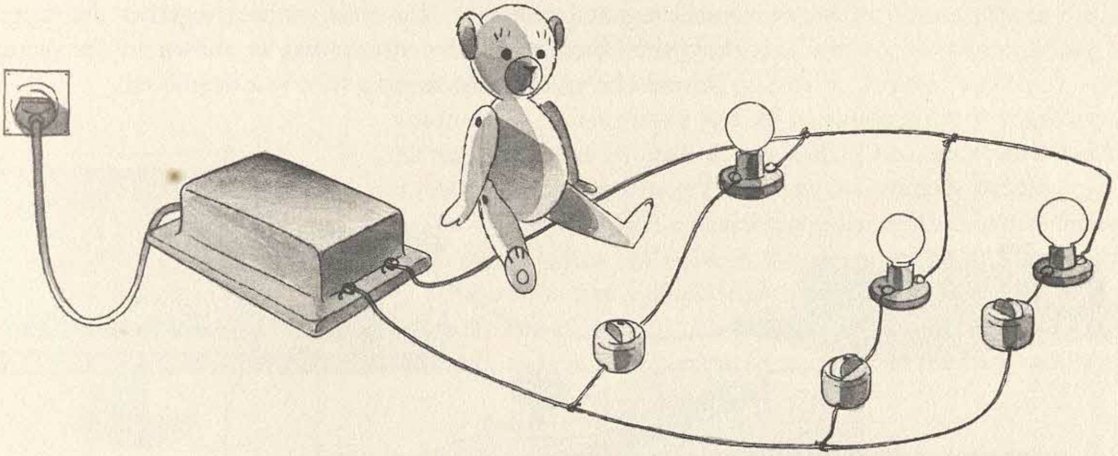
Connect this electromagnet to the terminals of a torch battery. For preference use the flat type which consists of three cells and gives a voltage of 4½ volts. But take care not to have your electromagnet connected to the battery for too long at a time because it uses quite a lot of current and the battery will soon be run down.

The terminal of the battery which is connected to the zinc container is the negative pole, the other is positive. As the battery is fitted with strips of brass for terminals it is easy to find which is which. The longer one is the negative and the shorter the positive. In one of these 4½ v. batteries three 1½ v. cells are connected together in series, that is, with the negative pole of one connected to the positive pole of the next one. By connecting cells or batteries in series you get the sum of the separate voltages. In parallel connections, in which all the positive poles are joined together, likewise the negative poles, you get no increase in voltage but you do get a larger current.



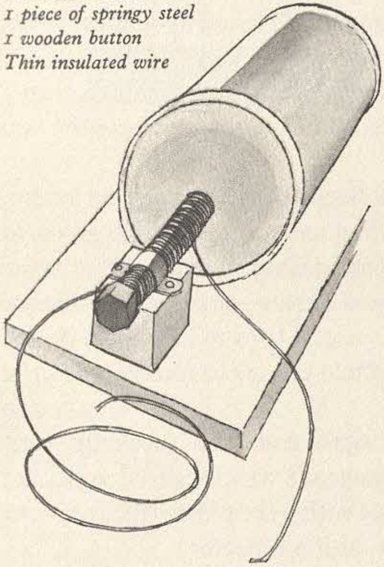


If you intend to use several small lamps it is probably an advantage to use a transformer as your source of power. A bell transformer, or a train transformer, will reduce the dangerous mains voltage to 4 or 6·3 volts. Lighting with small lamps can be very attractive in a doll's house, model garage or shop. Moreover, a small, portable lamp on a flex will be very handy for all sorts of experiments described in this book.



Make a buzzer . . . and send messages

1 electromagnet
1 empty vegetable can
1 bell transformer
Some small nails
Some pieces of wood
1 piece of springy steel
1 wooden button
Thin insulated wire

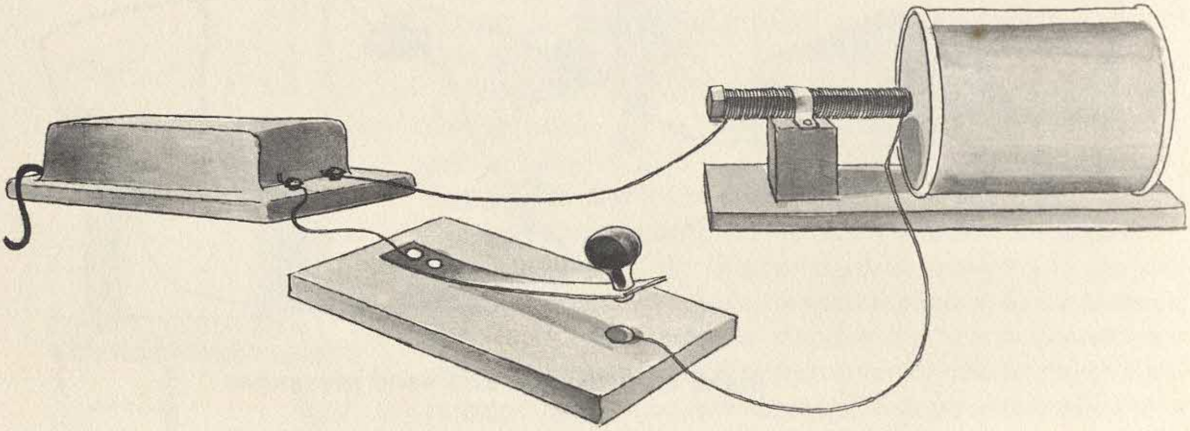


You can make a buzzer with your electromagnet. Nail an empty vegetable can to a small board. Now, the idea is that one end of the electromagnet should be put very close to the centre of the bottom of the tin. To do this, fix a block of wood to the board of such a height that when the electromagnet lies on it, one end of the core is at the same height as the centre of the tin. Now secure the electromagnet to the block with a strip of tin, in which two holes have been bored to take a couple of screws which will hold it to the wood.

Connect the electromagnet to a bell transformer or a model train transformer, so that the voltage remains at a safe 4, 6 or 8 volts. When the current is switched on you will hear a buzzing sound because the bottom of the tin is being attracted and released at very high speed and so it vibrates. By moving the magnet to and fro slowly we can find out at what distance between the tin and the magnet the sound is loudest. Do not let the buzzer work for too long at a stretch because the transformer may get overheated and burn out.

If we want to send messages with our buzzer we must make a tapper. Clean a strip of springy steel thoroughly with sand or emery paper. Bore three holes in it and then bend it. At one end fasten a flat or round wooden knob with a round-headed screw. With two more screws fasten the strip of steel to a small piece of wood into which you have already screwed a round-headed screw. File the two round heads, which must come directly one above the other, so that they are quite clean and make good contact when they are pressed together.

Now we have a tapping key and a buzzer or sounder and we are ready to send messages. We must connect together the tapping key, the sounder and the transformer as shown in the picture. It would be great fun to fix up a wire to a neighbour.



Press the knob of the key down, and the buzzer says 'prrr'. Hold it down longer and it says 'prrrrrrr'. In this way it is possible to send telegraphic messages in Morse code. The code is printed on page 51. In order to learn to signal rhythmically you must count aloud: one-two-three, one-two-three and so forth. A dot lasts for one count, a dash for three; between the signs which make up a letter count one, between two letters count three, and between two words count five.

You can practise with a friend. Begin with the simplest letters, those which consist of one or more dots: e, i, s, h. Then go on to the letters consisting of one or more dashes: t, m, o. Then write down a few words made from these letters—preferably nonsense words. You send them while your friend tries to take them down. After a while let him send to you while you try to receive and write down.

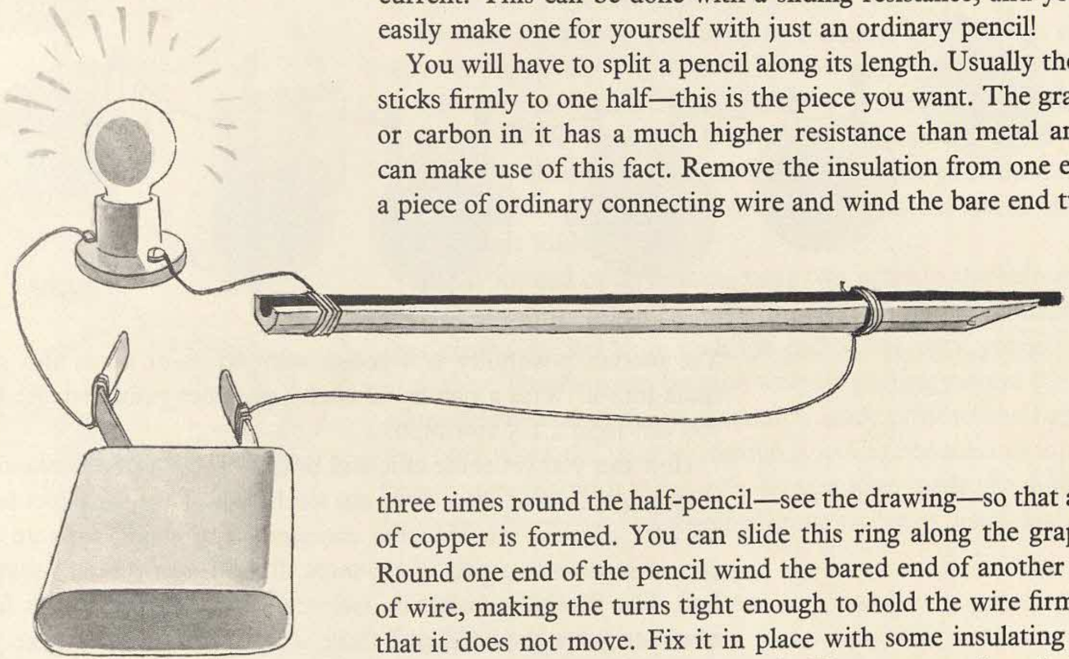
It is worth while learning the signs and their meanings well, for you will then know a secret language which can be useful for all sorts of purposes. You can signal with a lamp too—then you can exchange your buzzer for a lamp with a reflector.

A variable resistance

1 pencil
1 knife
Insulated wire
1 torch bulb
1 battery
Insulated tape

You can do a number of delightful things with those small, low-voltage torch bulbs. If you can get some suitable lampholders for them (they cost about 6*d.* each) experiments will be easier. You can illuminate a miniature grotto, or you can fix up a doll's house or a model railway with electric light. You can get the electricity from batteries, or you can use a transformer which converts the dangerous high voltage of the mains to a much safer, lower voltage. It would be an added attraction if you could raise or lower the lights just as they do in the cinema or theatre, but for this you would need to have some way of controlling the strength of the current. This can be done with a sliding resistance; and you can easily make one for yourself with just an ordinary pencil!

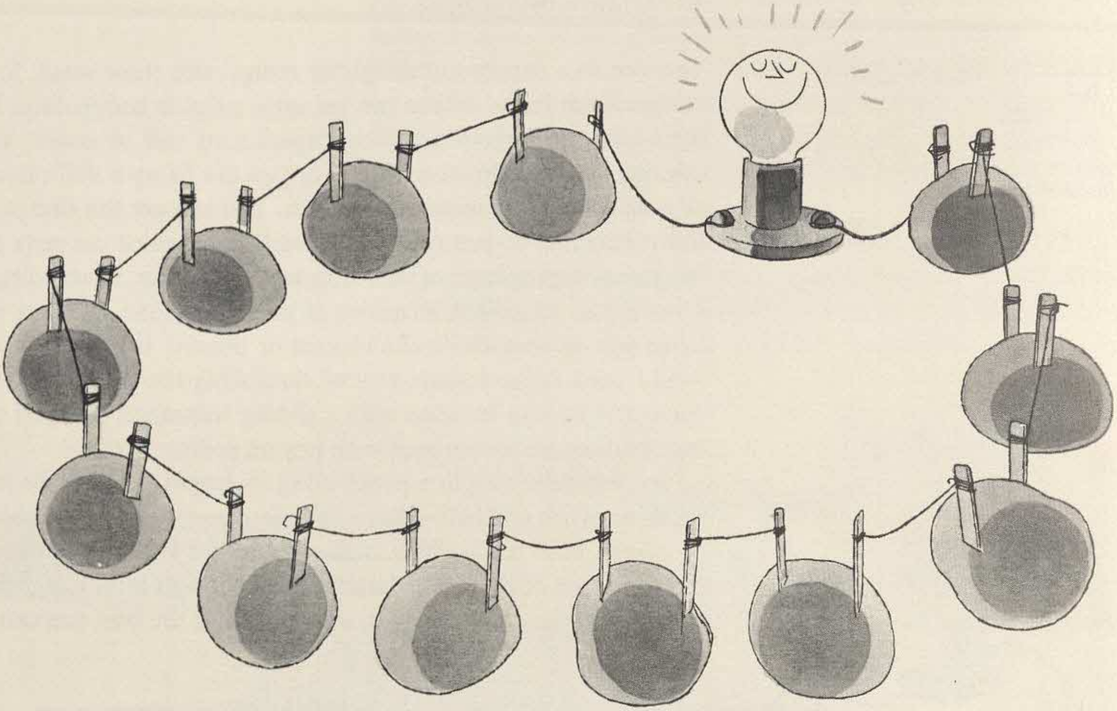
You will have to split a pencil along its length. Usually the lead sticks firmly to one half—this is the piece you want. The graphite or carbon in it has a much higher resistance than metal and we can make use of this fact. Remove the insulation from one end of a piece of ordinary connecting wire and wind the bare end two or three times round the half-pencil—see the drawing—so that a ring of copper is formed. You can slide this ring along the graphite. Round one end of the pencil wind the bared end of another piece of wire, making the turns tight enough to hold the wire firmly so that it does not move. Fix it in place with some insulating tape. Now your variable resistance is ready. If you connect it to the lamp and the battery as shown in the drawing, you will be able to regulate the brightness of the lamp just as you wish by sliding the ring along the graphite.



A lamp that runs on twelve potatoes

12 potatoes
Copper wire
1 1·5 volt torch bulb
1 lampholder
12 strips of zinc from old torch cells
12 strips of brass

There are many ways of making an electric cell. You need two different metals, or one metal and carbon, in an acid solution. You could use dilute sulphuric acid in a small jar with a zinc rod and a copper rod; or a lemon with a silver fork and a steel knife stuck into it, or even a silver coin and a bronze coin with saliva in between!



Yet another possibility is a potato with strips of brass and zinc stuck into it! With a battery of twelve potatoes prepared like this you can light a 1·5 volt bulb.

How can you get some zinc and brass? Zinc is not so difficult if you can get hold of some worn out torch cells. Take the paper label off and you can cut the zinc container into strips with an old pair of scissors or a pair of tin-snips. Brass is not quite so easy to find. Flat flashlamp batteries, twin-cell cycle lamp batteries have brass strips on them. Maybe there is a shop near you where you can buy thin strip brass. If you have enough copper wire you can use this instead. Wind bare wire round strips of wood (lollypop sticks) or cardboard.

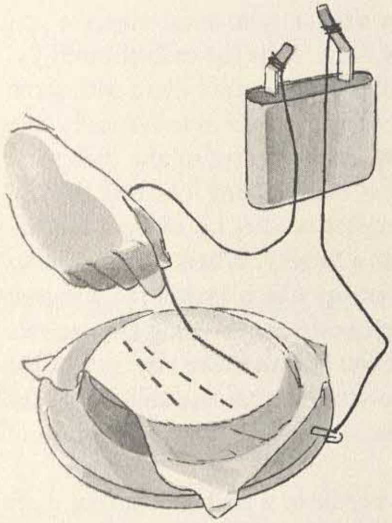
Now, in each potato make two cuts about half an inch apart. Into one push a strip of zinc and into the other a strip of brass. These twelve potato cells must be connected together in series. You do this by connecting the brass strip of one to the zinc strip of another with a piece of the copper wire. Connect the last two wires to the bulb and it lights. (If it does not, check that all your connections are good and tight.) A real battery gives a longer lasting light, of course, but isn't it fun to have made an electric battery from a dozen potatoes? It's something different anyway—a potato light!

'See' an alternating current

1 metal plate or lid
1 piece of cloth
Some cornflour, flour or starch
1 battery
2 copper wires
1 bell transformer

The electric current which we get in our homes from the mains is, for the vast majority of us, an alternating current. That is, a current which reverses its direction many times a second and whose strength increases and decreases too. Direct current, such as is given by a battery or accumulator, flows steadily with the same strength in one direction only. We can show the difference between direct and alternating current very neatly.

On a metal lid or aluminium plate lay a piece of cloth which you have soaked well in a paste made of cornflour, flour or starch mixed with potassium iodide, obtainable from the chemist. Wring the cloth out a bit before you lay it on the plate.



Connect the negative terminal to the plate by a piece of copper wire. A paper clip will help to make a good connection. To the positive terminal connect a piece of wire whose other end you then stroke across the wet cloth. On the cloth appears a long dark blue streak. The electricity liberates iodine from the potassium iodide, the iodine forms a dark blue compound with the starch and this appears as a line.

But if, instead of connecting your two wires to the battery, you connect them to a bell transformer with a safe low voltage, and then stroke the wet cloth with the end of one wire, you get a line of dashes. This happens because with alternating current the metal plate and the end of the wire are alternately positive and negative; and only when the wire is positive is iodine liberated to form the blue compound with the starch. So you have made the difference between alternating and direct current visible as small dashes.

Test for polarity

1 potato
2 copper wires
1 glass
Water and vinegar
1 battery

Previously, in the days when doorbells and house telephones were operated by direct current, there used to be used a very handy and cheap way of finding out which of the leads was connected to the positive of a battery . . . a potato!

Shall we do the potato-polarity test too? Cut off a potato a slice not more than half an inch thick. Stick into it the ends of two copper wires as close together as possible without actually touching, connect the other ends of the wires to the terminals of a battery. After a few minutes pull the wires out. If you look carefully you will see that one of the holes is coloured blue-green. The wire which was in the hole was connected to the positive terminal, and as a result a chemical reaction took place liberating a dye.

Do you know another method yourself of finding out which is the positive lead? What about a glass of salt water? You can also do it with a glass containing a little vinegar. Bubbles of gas—hydrogen—come from one of the wires, and this wire is connected to the negative terminal. So the wire which is connected to the positive must be the other one!

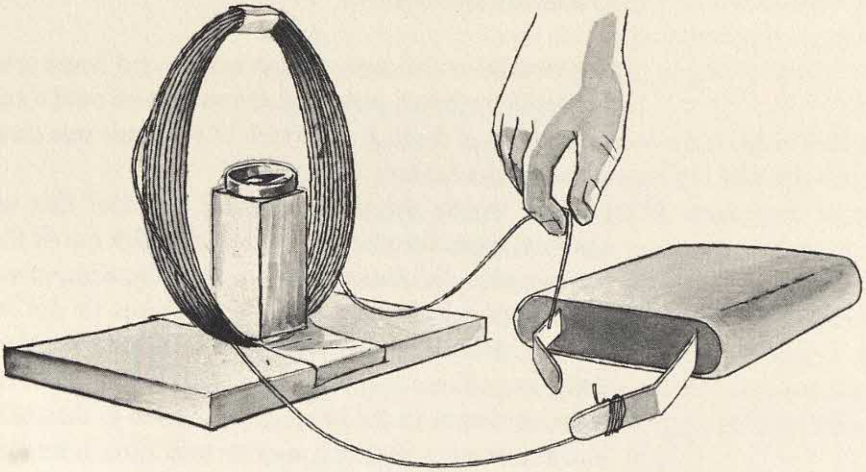
Make a galvanometer

Some thin insulated wire
1 bottle or cylindrical object
1 needle
1 magnet
1 piece of wood
1 compass

With quite simple materials you can make a very sensitive galvanometer—a meter in which the deflection of the needle gives an indication of the strength of the current.

Wind round a bottle or some similar cylindrical object a coil of 20 to 30 turns of thin insulated wire. Take the coil off carefully, press the turns together into a flat coil and secure them with some adhesive tape. Then fasten the coil with more tape vertically to a small board. On a little platform in the centre of the coil put a compass, and your galvanometer is ready. Turn it so that the coil lies in the same plane as the compass needle, i.e. along a North–South line, and connect the coil to a battery. When a current flows in the coil, a magnetic field is set up which makes the compass needle turn from its North–South position. By using the variable resistance described on page 69 you can alter the strength of the current, and you will be able to observe that the amount of the deflection of the compass needle depends upon the strength of the current.

If you have not got a compass needle or a pocket compass, there are two other ways of dealing with the situation. You can magnetize a steel needle by stroking it, in one direction only, several times



with the same pole of a magnet. Hang the needle by the middle from a thin thread which you can fasten to the inside of the top of the coil. Alternatively, you can float a magnetized needle or razor blade on a little vessel of water which you can place inside the coil. If you think that a steel needle or razor blade will not float on water because it is so much denser, then you must try it. If you lay the needle or razor-blade very carefully on the water, you will find that it does float—thanks to surface tension.

The majority of voltmeters and ammeters which you will see in electrical installations of all kinds work on the same principle as your galvanometer, but in most cases the magnet is fixed and the coil, fitted with a pointer, rotates.

A galvanometer like this can be made so sensitive that it will move if it is connected to a battery made from a lemon in which you have pushed a copper wire and an iron wire, or a cell made from two coins of different metals held together with some saliva in between them.

A loudspeaker as a microphone

1 radio receiver or gramophone amplifier
1 extra loudspeaker

In technology and in science many processes are reversible. Sound waves make a membrane vibrate; a vibrating membrane produces sound waves. By making a dynamo rotate electricity is generated; but send electricity into a dynamo and it turns round. So with a loudspeaker: electrical vibrations make it give out sound vibrations —and sound vibrations can set up electrical vibrations.

Have you by any chance got an extra loudspeaker in your house? Or maybe you can pick one up cheaply at a jumble sale or somewhere like that. An old loudspeaker, provided that it has a permanent magnet, will serve excellently as a microphone. How? By attaching the plug from it to the pick-up socket of your radio. Try it! But do not put your loudspeaker-microphone close to your radio. Otherwise it will scream at you, owing to what is called acoustic coupling. You can understand quite easily how this happens. A sound which the microphone receives is passed on via the amplifier to the loudspeaker of the radio and so the sound is re-emitted much louder. But the loudspeaker-microphone now 'hears' it again, picks it up and passes it on again to the loudspeaker of the radio. This amplifies it still more, so that the microphone hears it yet again, and so on. All this happens so quickly that you hear an excruciating screech.

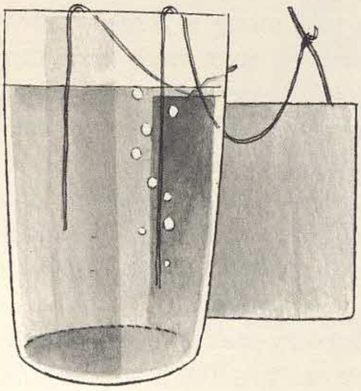
Perhaps you can set up your loudspeaker-microphone in another room. Then it will work best. You can play the part of a radio announcer and announce your own programme which people can listen to. You can sing a song or two, or play a bit of music, or play a game in which your listeners have to identify a variety of different sounds. You could surprise the guests at a birthday party by suddenly announcing a special news bulletin with special greetings for the one whose birthday it is.

A chemical works in a drinking glass

1 drinking glass
Cooking salt
Water
1 battery
2 copper wires

Fill a drinking glass with water and dissolve a good quantity of salt in it. Hang in the water two copper wires which you have connected to the terminals of a battery. A cycle lamp battery will do very well. If you look you will see bubbles of gas rising from the wire which is connected to the negative terminal. The gas is hydrogen. But from the wire connected to the positive terminal only a little gas appears; most of it dissolves in the water, but you can smell it: chlorine. This gas is very dangerous in large quantities, but in this case is pretty harmless. After a while you will see a green deposit collecting on the wire connected to the negative.

With the electricity you have caused all sorts of complicated chemical reactions. Cooking salt is a compound of sodium and chlorine and it has been split into its separate components by the electricity. The water too, which is a compound of hydrogen and oxygen has been split and the hydrogen has been set free. The sodium combines with a component of the water to form sodium hydroxide, caustic soda, which reacts with the chlorine forming sodium hypochlorite and with the copper wire producing the green copper salt. Altogether you have got a complex chemical works in your glass!



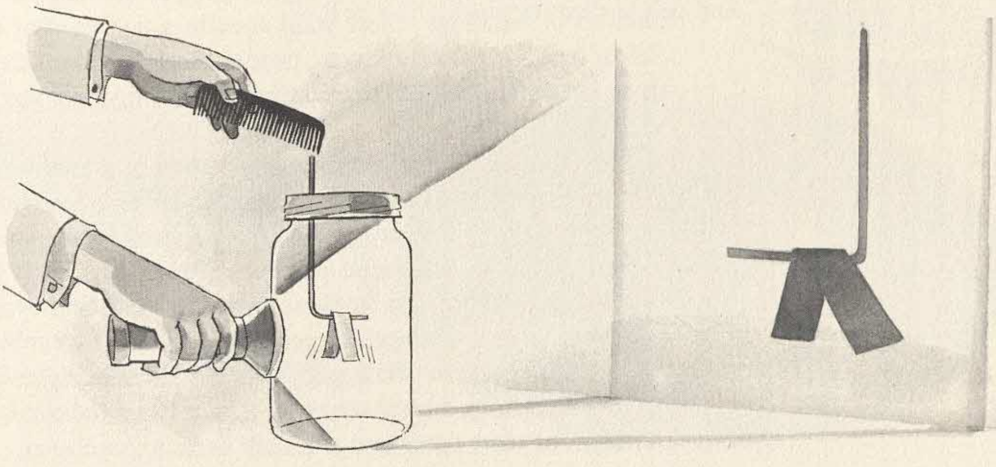
Make a shadow electroscope

1 jam jar
1 knitting needle or piece of copper wire
Aluminium foil
Torch or torch-bulb and battery

Wash out a jam jar very well with hot water and soap, and then make sure that it is quite dry by leaving it on or in the stove or out in the sunshine for several hours. Push through the metal lid a knitting needle or piece of copper wire whose end you have bent into the shape of a hook. Over the hook hang a strip of aluminium foil folded double. Suitable foil can be found in a cigarette packet or round chocolate. Use the thinnest that you can find, for the thinner it is the better your electroscope will work. If the foil has a paper backing, remove the paper very carefully. If you can get a strip of gold foil, for instance off one of the gold-tipped cigarettes, that will be even better.

Now charge some object with electricity—for instance by rubbing a comb through your hair, by rubbing a fountain pen or ball-point pen with a woollen cloth—and hold it near the end of the metal rod. You will see the ends of the strip of aluminium spring apart; each repels the other because each carries the same electric charge. You will notice that it is not necessary to hold your charged object against the lid; the experiment works from a distance. The greater the charge, the more strongly the two halves of the aluminium leaf repel each other, and the further apart are the ends. So the apparatus can be called not only an electroscope but an electrometer—for if you can measure the distance between the leaves you can compare the sizes of various electric charges.

It is well worth while to make a magnified image of the aluminium strip. You can do this by standing a torch, or hanging a torch-bulb connected to a battery by a piece of flex, in front of the jam jar, so casting a large shadow of the leaves on the wall or a piece of white cardboard. By this method you can easily obtain a

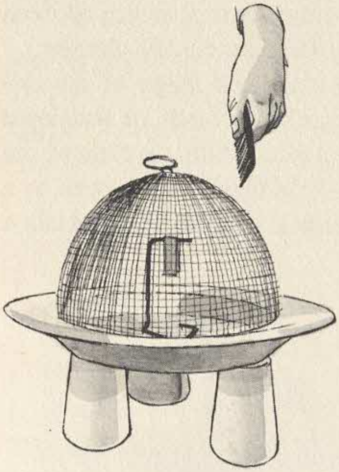


magnification of many tens of times, so that a movement of the leaves of a mere fraction of an inch becomes, on the wall, an inch or more. You can mark a simple scale on the side of the jar between the foil and the wall with Indian ink, and this scale will be projected on the wall too. In this way you can get very near to making the shadow electroscope which was formerly used very frequently in scientific research.

Faraday's cage

1 metal wire meat cover
1 dish or plate
1 comb
1 electroscope
3 or 4 plastic beakers

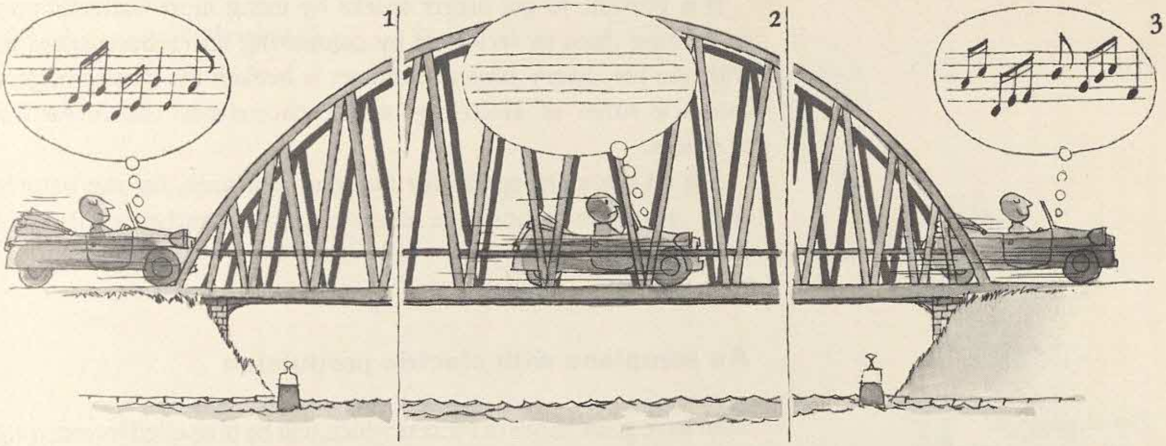
The great scientist Michael Faraday was a brilliant experimenter who never despised the use of quite ordinary domestic utensils for his experiments. One well-known example is his famous Ice-pail experiment which he carried out during his investigations into induced electric charges. During these same researches he made use of what was to become renowned as the Faraday Cage, originally a cage of wire netting on a brass frame. By means of an electroscope placed inside it he was able to show that no matter how large a charge of electricity there is outside the cage, and even if this charge is passed to the cage itself, no charge whatever can be detected inside it. Faraday even got into the cage himself to investigate this. The charge which is on the cage resides wholly on the outside.



Nowadays the term Faraday Cage is used for any space surrounded by a metal gauze, bars or plates in which the interior is completely screened against static electricity and radio waves. Sometimes such cages are constructed for such purposes as carrying out very precise measurements with extremely sensitive instruments. Frequently such cages occur in various types of structure: for instance, the cabin of an aeroplane, the inside of a car and the interiors of buildings whose walls contain a fair amount of steel. Ships, too, are Faraday Cages; inside them there is little danger from lightning—the electric charge stays always on the outside surface.

You can make a very serviceable imitation of a Faraday Cage if you can get one of those wire-gauze meat covers which used to be very common in the days when refrigerators were not so well known. Stand it on a metal plate or dish supported on three or four plastic beakers. Put an electroscope inside it and bring up to the meat cover a comb which you have charged by rubbing. You will observe that the electroscope shows not the slightest movement as the charged comb approaches, nor when the comb actually touches the meat cover and transfers some of its charge.

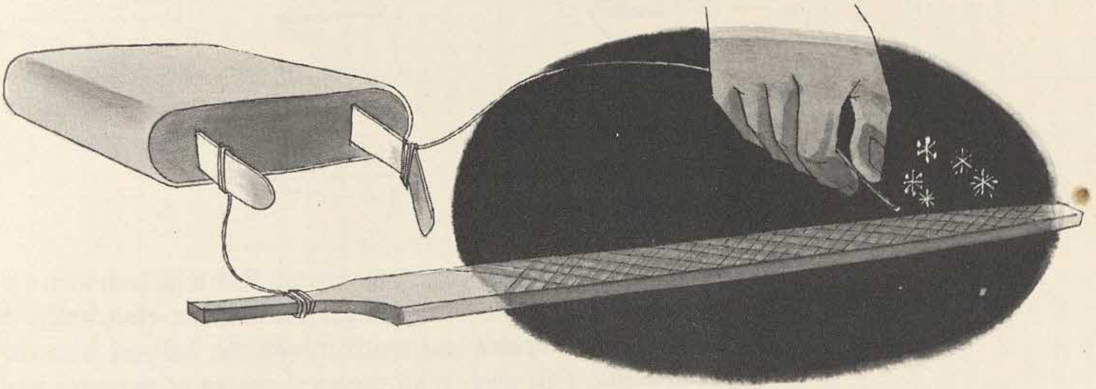
The fact that radio waves are held back by a network of metal bars can be shown quite easily when you drive in a car, with the radio on, across a bridge of metal girders. The radio stops or becomes much fainter. You will also observe it if you take a transistor set into a space surrounded by a metal framework. I'm going to try a few experiments there!



Make your own electric sparks

1 battery
2 copper wires
1 file

Electric sparks make a wonderful show. Just think of lightning flashes. Now, we are not going to make great big flashes like that, but we are going to make a whole lot of little sparks. And we are going to do it with a file—a nail-file or any other kind of file will do. Use one of the wires to connect one end of the file to one of the terminals of the battery. Fasten one end of the other wire to the other terminal of the battery, then stroke the free end over the file. Showers of sparks come out. They look best if you do this experiment in the dark.



The sparks consist of very small fragments of white-hot steel. They cool down so quickly that they cannot possibly do any damage. As a matter of fact the stroking of the wire backwards and forwards along the file causes one short-circuit after another, but the current is continually being broken by the roughness of the file. The metal is so strongly heated by the current that the white-hot fragments are thrown out.

It is possible to get bigger sparks by using more batteries and connecting them in series, or by connecting an electromagnet in with the file. Every time the contact is broken the electromagnet causes a surge of electricity which encourages the formation of sparks.

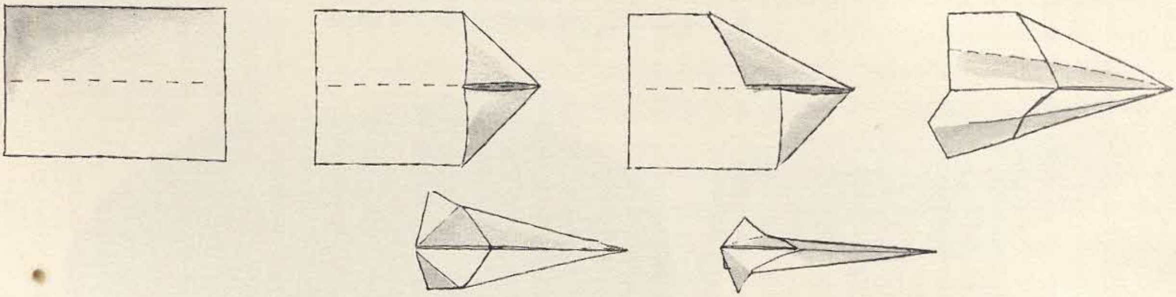
But do not make sparks for too long at a time, for the battery finds all these continuous short-circuits a rather exhausting business.

An aeroplane with electric propulsion

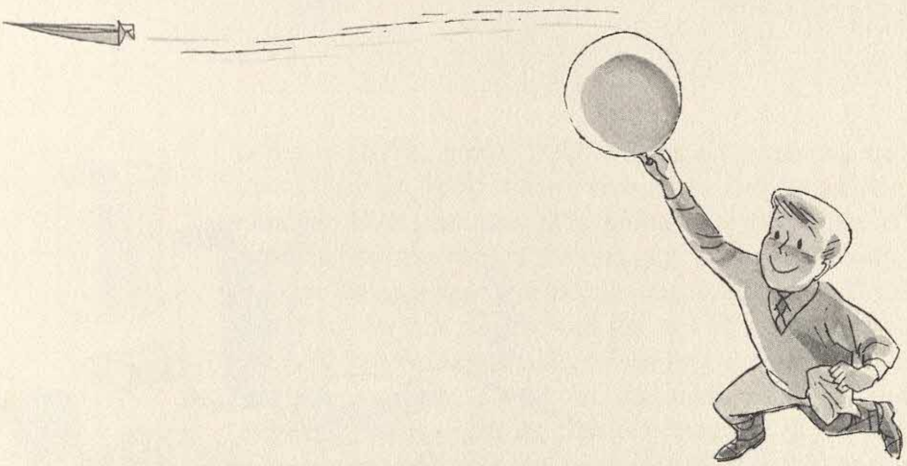
Thin aluminium foil
1 piece of woollen material
1 pair of scissors
Transparent tape
1 balloon

Men have great hopes of rockets which will be propelled by escaping ions—electrically charged atoms or molecules, which can be expelled at terrific speed. How terrific? The ion-rocket has not passed the laboratory stage yet, but there are hopes of hundreds of thousands of miles per hour, hundreds of times faster than the rockets powered by the fuels used at present.

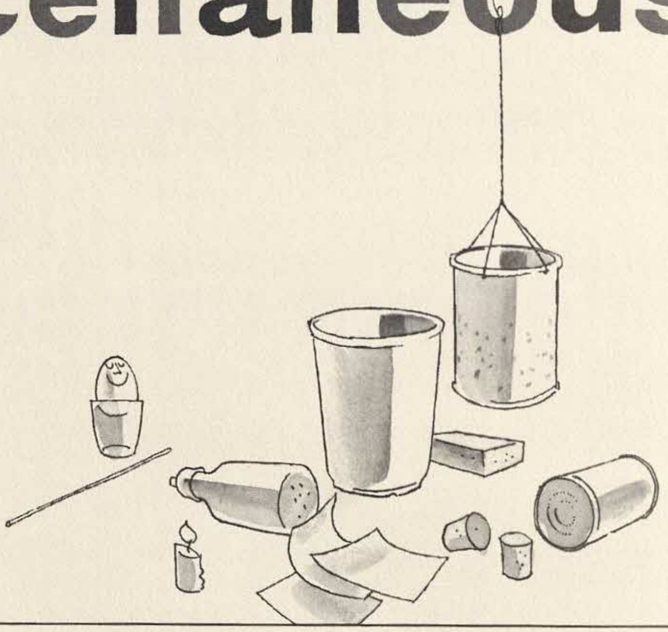
The aeroplane which we are going to make is also going to be driven by electric repulsion, but ions play no part in it. Fold a thin but fairly stiff piece of aluminium foil in the way shown in the picture. This will make a very simple glider, but we are going to get it to fly in a most unusual way.



Choose a dry day for this experiment. Rub a balloon with a piece of woollen material—this charges the balloon electrically. Now launch the aeroplane and touch it with the balloon immediately afterwards. This gives it an electrical charge of the same kind as the balloon. Now, if you approach the gliding aeroplane with the still charged balloon you can control the height, speed and direction of the glider, because the balloon and the glider have the same kind of charge and so repel one another. When you have gained some skill you can make your aeroplane fly faster and longer than when no electric force takes part in the game!



Miscellaneous

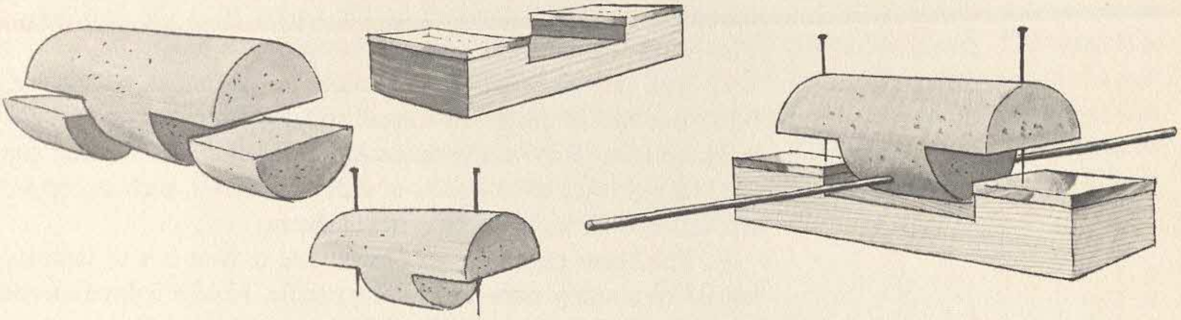


How to make a super-sensitive instrument

2 pins
1 cork
1 block of wood
2 pieces of glass
1 knitting needle
1 thermometer
1 sharp knife

'By Measuring to Knowing'—so said the famous scientist Kamerlingh-Onnes who was the first to liquefy the inert gas helium, and so knew how to produce such a low temperature that his laboratory in Leiden in Holland was for many years the coldest place in the universe. And in fact, modern science and technology depend to a very high degree upon very accurate measurement. Consequently it is interesting to make for yourself a measuring instrument of the very simplest construction which provides a very high sensitivity. Yes, without spending much it is possible to make an instrument which is as sensitive as a laboratory instrument: the balance which is attributed to Professor Zehnder of the University of Basle. With it you can make interesting measurements in the fields of air currents, heat and electricity. Two pins, a razor blade or very sharp knife, a cork, a block of wood, two pieces of glass, a steel knitting needle and a thermometer are all that you will need for this balance.

Push the needle through the cork just as is shown in the picture,



making sure that exactly equal lengths are projecting on either side of the cork. From the two ends of the cork cut out two half-cylinders. Now push two pins through the cork, again at equal distances from the ends of the cork. On the wooden block, which you have cut as is shown in the drawing, stick two small pieces of glass. Push the two pins through the cork far enough to allow the cork, with the knitting needle, to rest on the points without anything else touching. To get the maximum sensitivity from the balance you must adjust the pins very carefully. If the balance is not in equilibrium, push the knitting needle one way or the other until a balance is obtained.

You can carry out the following interesting experiments with this Zehnder balance:

A. To demonstrate the very great sensitivity of the balance, hang halfway along one arm an inverted V made of thin wire about an inch long, or of a very thin strip of paper. The weight is very small—only a few grains—yet the balance shows a definite deflection.

B. You can show gently rising air currents by holding a burning match under one end of the balance. A flat piece of paper stuck to each end of the needle will increase the sensitivity and show the air currents even more impressively. You should trim the paper with scissors to restore the balance.

C. Because the balance stands on little glass plates it is very well insulated. You can give the needle an electric charge by touching it with a comb which has been charged by rubbing it. Recharge the comb by rubbing it again and bring it up to one end of the charged needle. The repulsion is very clearly seen. You can demonstrate the attraction by not charging the needle first.

D. Magnetize the knitting needle by stroking it several times in the same direction with one pole of a magnet. The balance now becomes a kind of compass. However, it now indicates not the north pole but the inclination. The inclination is the angle which a freely swinging magnetized needle makes with the horizontal. The needle must be placed in a North–South line.

E. You can make a very sensitive galvanometer by placing below one end of the needle a small coil, say twenty turns, of thin insulated wire. The needle moves immediately if you connect the coil to a cell made of two coins of different metals, such as copper and nickel, with some saliva between them.

F. The linear expansion of a metal due to heat can be demonstrated very neatly with the knitting needle. Hold a lighted match or candle flame beneath one end. That arm of the needle expands—but does not get heavier—and the balance is no longer in equilibrium.

G. If you replace the needle by a long thin thermometer you can demonstrate the effect of heat rays—infra-red rays. The bulb of the thermometer must be covered with a thin layer of soot from a paraffin lamp or stove. Bring a lighted electric lamp or a glowing soldering iron over the sooty thermometer bulb. The heat rays are absorbed, the temperature rises and the mercury expands. One arm of the balance therefore becomes heavier and goes down. With a well-made and well-adjusted balance the sensitivity can be made so high that the instrument will react to the heat from the sun. As a good source of infra-red rays you can use a radiator. If the radiation from such a radiator or from the sun is suddenly stopped by putting your hand in the way the balance shows a reaction.

H. Very small movements of the balance can be made clearly visible by gluing a small piece of a broken mirror to the end of the needle. Of course the needle will have to be moved through the cork a little way in order to restore the balance. With very small swings of the needle a ray of light, for instance from a torch, is reflected at a different angle and a very large movement of a spot of light on the ceiling is obtained.

I. By giving the coil made for *E* a great many more turns and connecting it to what is known as a thermocouple it is also possible to render visible very small changes in temperature. A thermocouple, in which heat is converted to electricity, can be made with some constantan wire, obtainable in some shops which deal in radio parts. A piece of constantan wire is soldered to a piece of copper wire of about the same diameter. If you now hold a lighted match under the join there is, naturally, a rise in temperature. This results in the generation of an electric pressure, then a current flows which causes a movement of the balance.

J. Here is a way of demonstrating the quite fantastic sensitivity of your balance. We are going to use a combination of *H* and *I*.

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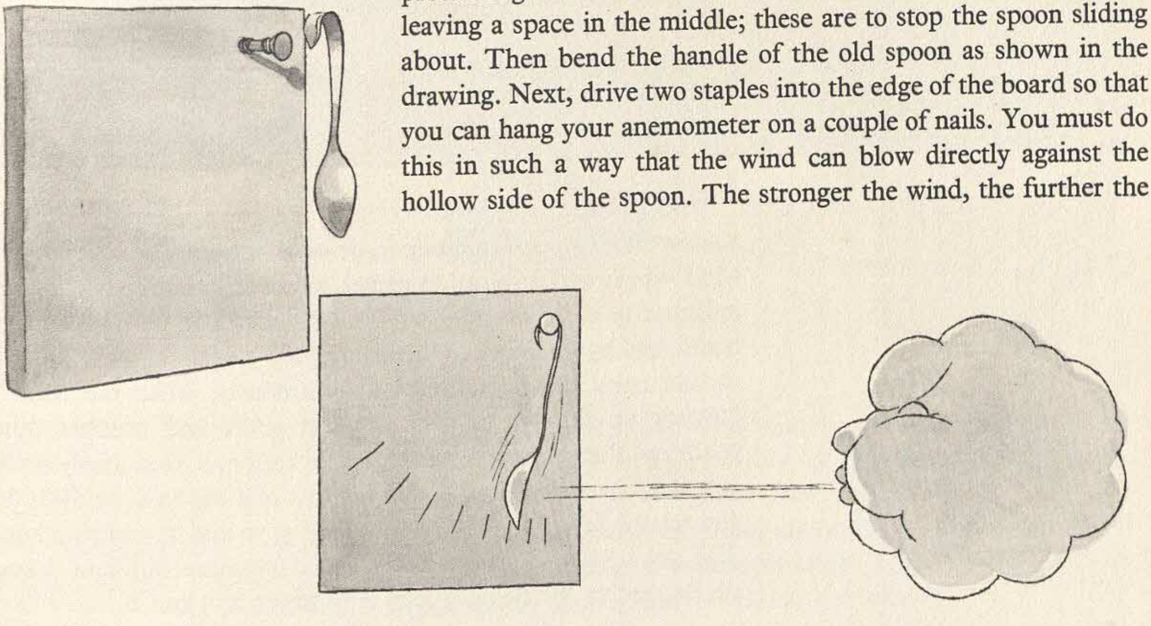
Hold the soldered joint between a finger and thumb and you should get a movement of the spot of light on the ceiling. The tension set up by the heat of your hand is less than a thousandth of a volt, the energy released is less than a millionth of a watt and less than a thousand-millionth of one horsepower. Nevertheless you can demonstrate these minute tensions and energies with your Zehnder balance. Thank you, Professor!

Make your own anemometer

1 square of wood, 3–4 in. side
1 long nail, 3 in.
2 elastic bands
1 old spoon
2 staples

An anemometer is an instrument for measuring the force of the wind, which depends on the speed of the air. At the weather stations the observers use anemometers which look like little horizontal windmills whose sails are little hemispheres. The number of revolutions per second is a measure of the force of the wind, but it is impossible to read this directly by trying to count the number of times the windmill goes round in a minute. Consequently a separate mechanism is needed, or else the windmill is allowed to drive a dynamo and the current generated is measured with an ammeter. Then the amount of current produced gives a measure of the strength of the wind.

The anemometer which we are going to make is not as accurate as those in weather stations but it does have the advantage that it can give a direct reading of the force of the wind. Drive a 3-inch nail into one corner of the small board leaving about 2¼ inches protruding. Wind elastic bands several times round the nail, leaving a space in the middle; these are to stop the spoon sliding about. Then bend the handle of the old spoon as shown in the drawing. Next, drive two staples into the edge of the board so that you can hang your anemometer on a couple of nails. You must do this in such a way that the wind can blow directly against the hollow side of the spoon. The stronger the wind, the further the



spoon is driven backwards and upwards—hence the position of the spoon gives an indication of the strength of the wind.

It was a British Admiral, Sir Francis Beaufort who, more than 150 years ago, built the first practical anemometer and devised the Beaufort Scale. You can fix a copy of this scale, which is in use all over the world, on to your anemometer.

This is the Beaufort Scale:

Beaufort scale no.	*Description*	*Noticeable effect on land*	*Speed in m.p.h.*
0	Calm	Smoke rises vertically	0
1	Light air	Wind direction shown by drift of smoke	1–3
2	Slight breeze	Wind felt on face: leaves rustle: flags stir	4–7
3	Gentle breeze	Leaves and twigs in constant motion: wind extends light flags	8–12
4	Moderate breeze	Dust and small branches moved: flags flap	13–18
5	Fresh breeze	Small trees in leaf begin to sway: flags ripple	19–24
6	Strong breeze	Large branches in motion: flags beat	25–31
7	Moderate gale	Whole trees in motion: flags extended	32–38
8	Fresh gale	Twigs break off trees: walking is hindered	39–46
9	Strong gale	Slight structural damage to houses (e.g. slates removed)	47–54
10	Whole gale	Trees uprooted: much structural damage to houses	55–63
11	Storm	Widespread damage	64–75
12	Hurricane	Excessive damage	over 75

Now how can you calibrate it, or mark it out? The speed of the wind which makes large branches move will force your spoon-indicator to a certain position. This position can be noted on the board, and by reference to the scale above we see that it is Force 6, so that mark can be numbered 6. Similarly, when the wind is blowing at different speeds you can mark and number other positions. But perhaps a better way to calibrate your anemometer is to hold it carefully out of the window of a car on a windless day and ask the driver to drive at speeds of 5, 10 and 27 miles an hour. The positions taken up by the spoon at these different speeds correspond to the Beaufort Scale numbers 2, 3 and 6.

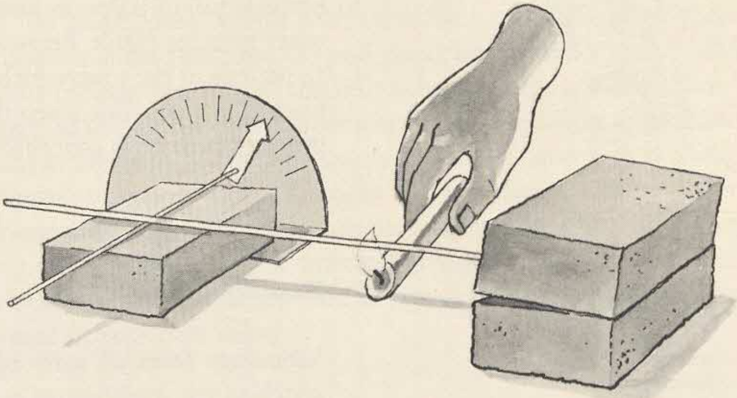
Expansion by heat revealed

3 bricks
1 metal rod
1 darning needle
1 piece of cardboard
1 candle

Nearly all materials expand when they are heated. It is on this fact that the thermometer depends. With rise in temperature the mercury in the bulb expands and rises up a very narrow tube. There are also thermometers which make use not of the expansion of a liquid but of a solid. Let us make a model of one of this type of thermometer—and at the same time show the expansion of solids very neatly.

Across two bricks lay a metal rod, or a length of wire cut from a metal coathanger will do. On one end place the third brick or a similar heavy weight to prevent it from moving. Under the other end of the rod put the darning needle. Make a pointer from stiff paper, thin card or a drinking straw and fix it to the end of the needle. You can also make a semicircular scale on card and set it up behind the needle. Look at the drawing.

Hold a burning candle under the rod and move it slowly backwards and forwards along the rod so that it gets heated. Watch the pointer. You will see it move. This shows that the rod has expanded, its expansion being magnified by the motion of the needle. The coefficient of expansion of the iron is 0·0001. That is to say that the iron expands by 0·0001 of its original length for every degree increase in the temperature. This is a very small amount, yet our apparatus is able to make this minute expansion clearly visible.



Though the expansion is so minute, engineers have to allow for it. A rail 45 feet long, with a rise of temperature of 30°C becomes $45 \times 12 \times 30 \times \cdot0001$ or 0·16 inches longer. In order to prevent the rails from becoming distorted by expansion a gap is left between the ends of consecutive rails. The ends of bridges are supported on steel rollers for the same reason.

Play a scientific trick on someone

1 strong plastic bottle with a screw stopper
1 nail
Water
1 willing but good-tempered victim

The best way to impress some scientific principle on someone so that he will never forget it is to play a scientific trick on him, a trick in which he is the victim. Afterwards, of course, you tender your apologies and offer an explanation. The following experiment is eminently suitable for this purpose.

Liquid detergents are sold in plastic bottles with screw tops. In the bottom of one of these bottles make a number of very small holes. You can do this with any sharp-pointed instrument, a nail for instance. In case of difficulty you can wrap one end of the nail with a bit of rag, or hold it in pliers, and heat the point in a flame. Now you should find it quite easy to make holes in the bottom of the bottle.

When the bottom of your bottle leaks like a sieve, immerse it in water until it is quite full. Screw the cap on tightly and lift it out. You could use a cork provided that it is a perfect fit. When you lift the bottle out of the water you will find that the water does not run out.

Give the bottle to someone and ask him if he thinks that he is strong enough to get the top off. When he succeeds the immediate result is that the bottle empties through the holes in the bottom. Don't forget that your victim is going to get wet, and be sure that the result will not be too catastrophic. . . .

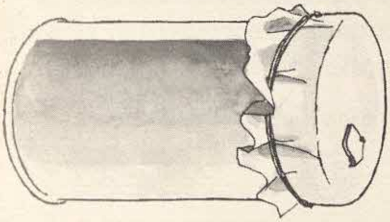
The explanation is quite simple. Even though the bottom of the bottle is full of holes, as long as it is tightly closed at the top the water remains inside because the pressure of the atmosphere, at 14 pounds to the square inch is great enough to prevent the water from falling out. But when the airtight stopper is removed the air pressure beneath is cancelled out, the water is no longer held back —and so . . .

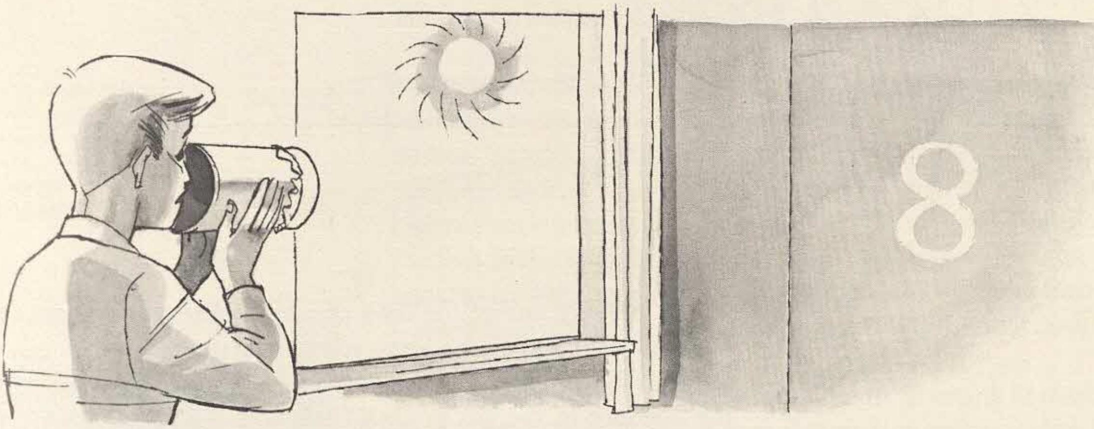
Seeing sound

1 tin can
1 rubber balloon
1 pair of scissors
1 old mirror
Gum or glue
1 sun
A few elastic bands

Vibrations from all sorts of machines, ranging from the tiniest watch to the mightiest of steam turbines—not only sound vibrations but also the most complicated electrical vibrations up to many millions a second—can be made visible by means of an electrical instrument known as the cathode ray oscillograph. This instrument is of immense importance in scientific and technical research because it enables the vibrations to be studied very accurately.

An oscillograph is a very costly and intricate instrument, so we are going to construct with very simple materials a light-ray oscillograph which will render sound vibrations visible. We start by cutting a piece of rubber from a balloon and stretching it tightly over a tin can from which we have removed both ends. Now we are going to need a very small piece of mirror, a fragment smaller than half an inch square. The only way to get it is to put an old or broken mirror into a strong paper bag, fold the bag over several times so that the mirror is covered by several layers of paper and then to tap it with a hammer. Pick out your mirror fragments, wrap up the rest carefully and put it in the dustbin. Glue the piece of mirror (which doesn't have to be square) to the stretched rubber on the can, not exactly in the centre but slightly to one side of it.



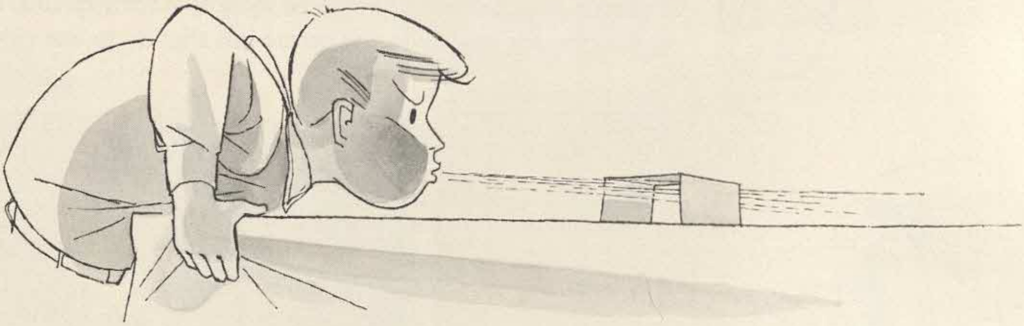


To make sound visible with your light ray oscillograph there must be some sunshine. Go and stand by the window and hold your oscillograph so that the little mirror reflects a beam of sunlight on to the wall. You will see a little spot of sunlight there. Now sing as loudly as you can into the tin all sorts of notes such as a long drawn out oooooooo . . . aaaaaaaa . . . eeeeeeee . . . iiiiiii . . . or uuuuuuuu. The little mirror vibrates making the spot of light on the wall produce different patterns, giving a picture of the sound vibrations as sound waves. And so you are able to see sound—the sound of your own voice!

It doesn't work!

1 piece of thin card 2 in. × 6 in.

There are some experiments which always surprise everybody because the result is totally different from what is expected. Here is one of these experiments, as simple as it is incredible. Take a piece of thin card or very stiff paper about 2 inches by 6 inches; fold the ends down so that you make a little bridge. Stand it on the table and blow against it as the boy in the drawing is doing. No matter how hard you blow you will not succeed in blowing the little bridge away, however smooth the table top! On the contrary, the harder you blow the more firmly does the little bridge seem to stick to the table. If, on the other hand you blow against the end of the bridge it is quite easy to send it a considerable distance. How is it that this extremely light paper bridge is not moved by blowing under it? It seems as though it is nailed to the spot.



It is obeying one of the laws of nature, discovered some two hundred years ago by the Swiss scientist Bernouilli, which can be stated as follows: as the velocity of a gas or liquid increases so does the pressure in the gas or liquid decrease. In other words: the greater the speed, the lower the pressure. When we blow, the air flows beneath the bridge with a certain speed. Consequently the air pressure under the bridge is lower than it is above. So the air on top of the bridge presses down on it—you could say that the bridge is sucked down against the table and the force which does this increases the harder you blow.

So give up blowing! You can blow like a hurricane, blow till you are purple and you will not succeed in blowing the bridge away!

Five in one

1 empty can
1 sharp nail
Water

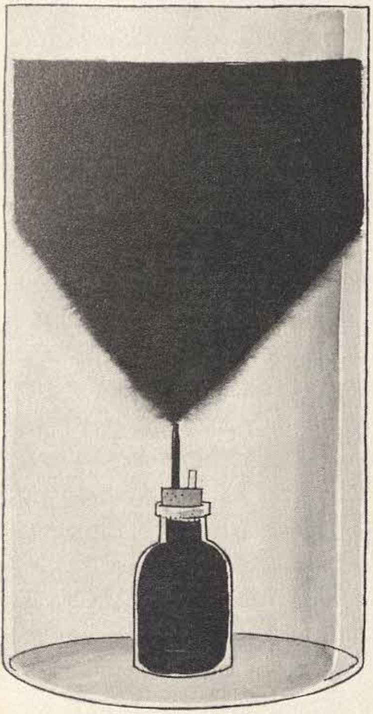
With a sharp nail make five holes in a can, about $\frac{1}{4}$ inch apart and near the bottom. Fill the can with water and five jets of water stream out. This is no surprise. But it is certainly surprising when you combine these jets into one with a wave of your hand. How? By pushing the jets together with the finger and thumb. Once they have made contact with one another they do not get free again.

This phenomenon is caused by surface tension. The surface of water, and of other liquids, behaves like an elastic skin. This explains why some insects are able to walk on water, and why a needle or razor blade floats on water if you lower it very gently on to the surface with something like a fork. If you are very careful you can do it just with your fingers.

The outsides of the five water jets also have surface tension and this is the reason why, as soon as they have touched one another, they stick together. By moving your hand along the five jets you can restore the original situation, five separate jets: one movement of your hand and they are joined together again.

An underwater volcano

1 large glass bottle or jar
1 small glass bottle
Some ink
1 cork
1 glass tube with a tapered end
1 glass tube
Water



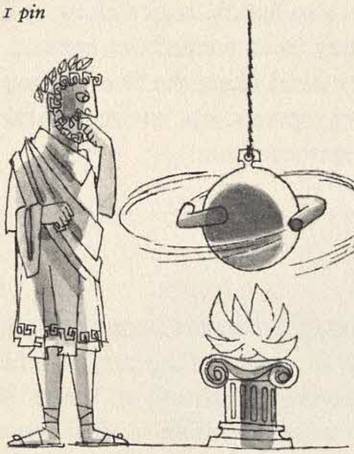
Underwater volcanoes can cause dreadful disasters because, when sea water penetrates down through the crust of the earth to the molten 'magma' underneath, an enormous amount of steam is suddenly generated. The escaping steam produces a tidal wave higher than a house. Such an explosion off the island Krakatoa in the East Indies in the last century caused thousands of victims. The underwater volcano which we are going to make is quite innocent —there is no fire in it. In fact it is not a real volcano but it does look a bit like one.

Bore two holes in a cork which fits tightly in an ink or similarly sized bottle. Through one of the holes push an ordinary glass tube and through the other a small tube with a tapered end (like the small tubes supplied with eyedrops). Look at the drawing and you will see how to fit the tubes. Now fill the small bottle with very hot water coloured deep blue with ink. Of course any other colour would do just as well. Push the cork with its two tubes firmly into the bottle. Put the bottle at the bottom of a large glass jar filled with very cold water. Now you will see a delightful thing. A funnel-shaped cloud of colour rises from the little jet just like the smoke and ash which rise from a volcano. This cloud continues to rise until all the hot coloured water in the little bottle has been replaced by cold water.

The explanation is this: the hot water is less dense than the cold water and so it rises, just as a balloon filled with hydrogen rises in the air. The denser cold water flows into the bottle containing the warmer water. This goes on until the water in the small bottle attains the temperature of the water around it.

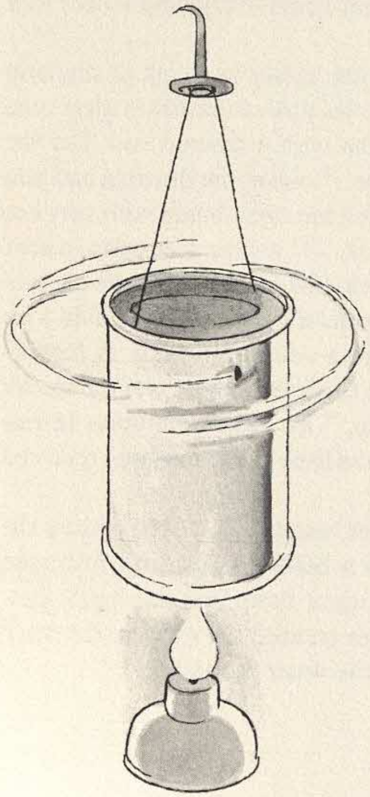
How to make a steam turbine

1 tin can with a lever lid
1 sharp pointed nail
Strong, thin twine
1 button with three holes
1 pin



At the beginning of our era, about two thousand years ago, when millions of people were living in slavery there was already in existence the prototype of a machine which was, eventually, to prove capable of producing more work than the combined efforts of all the slaves in the world: the steam engine. It was invented by a man called Hero who lived in Alexandria, and it consisted of a revolving metal ball with two short outlet pipes. Water was boiled in the ball, steam escaped from the pipes and the ball started to revolve in the opposite direction to that of the jets of steam. This first steam turbine was called an *æolipila*. The engine's only use was for demonstration or amusement. Even if the technology of the time had been capable of producing bigger and more powerful engines (which was unlikely), there was little inducement to do so. There was practically no need for steam power, for man-power existed in abundance—slave labour. In the eyes of the six million Greeks who ruled over them, the ten million slaves were just so many cheap machines.

In the latter half of the seventeenth century the steam engine at last emerged, and changed the course of history. According to the Belgian missionary Verbiest a steam carriage had earlier appeared in Pekin. From a charcoal-heated boiler, he said, there came a jet of steam which played on a paddle wheel. This in its turn made the wheels of a carriage rotate. In Europe, too, experiments were being carried out and in 1698 Savery constructed a steam engine which was nicknamed 'the miners' friend' because it pumped water out of the mines.



If you know how to bend two glass tubes and draw them out to fine nozzles you can copy the *æolipila* of Hero. Get a can with a tight-fitting lever lid, such as a syrup tin, and make two holes in the sides which will take rubber stoppers. The glass tubes should fit through holes in the stoppers. Put about an inch of water in the can and push the lid on tight. Hang the whole thing up, as shown in the picture, over a flame. When the water boils your boiler with its jets starts to rotate—in the opposite direction to that of the steam.

There is a simpler way of doing it: instead of fitting the glass tubes, you can simply bore two small holes in the tin with a very sharp nail. Make the holes in such a way that the steam does not shoot straight out but at an angle to the tin. You can do this by twisting the nail as far as possible to one side after you have driven it through the tin. Be careful not to make the holes too big—$\frac{1}{10}$ inch diameter will be about right. The best way of suspending the tin is by putting some strong elastic round it. You can make it 'spinnable' by suspending it from a button as the picture shows.

The steam escaping from the holes sets up a force of reaction which makes the tin move in the opposite direction, in the same way as in a jet aircraft the hot gases escaping backwards push the aircraft forwards. If you put hot water into the can your steam turbine will start sooner.

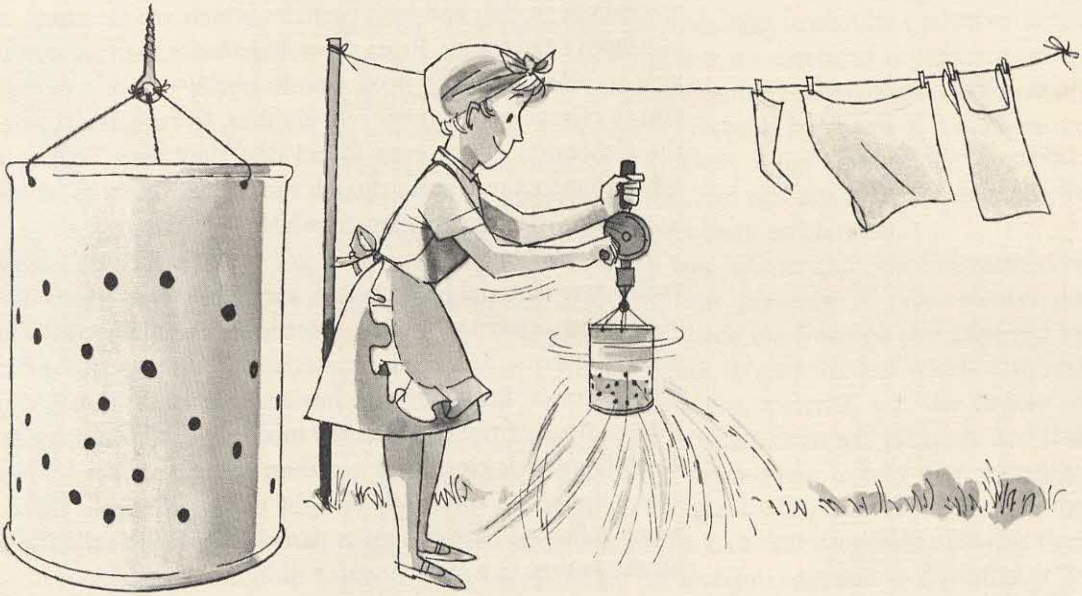
Make your own spin-dryer

1 empty can without a lid
1 nail
1 piece of string
Water
A cloth
1 hand drill

Not so many years ago washing clothes was one of the most laborious of tasks. The clothes had to be rubbed hard on a ribbed washboard and most of the water had to be removed with a wringer. With the possible exception of the vacuum cleaner no other machine has saved housewives so much labour as the washing machine combined with the spin-dryer.

It is quite easy to make a small working model of a spin-dryer. With a sharp nail make a large number of holes in a tin (a syrup tin will do nicely). Three of the holes must be equally spaced near the rim, so that you can hang the can from a screw eye which will be held in the chuck of a hand drill. Put a wet cloth into the can and spin the can round. Then, thanks to centrifugal force, the water is thrown outwards with such force that it shoots out of the holes. The wet cloth loses so much water that after the experiment it is barely damp.

A hand drill is a very useful thing for carrying out other experiments on centrifugal force. Replace the can by a flat lid and



place several heavy objects on it. They will be thrown off if the lid is rotated fast enough.

Get a can without a lid and without holes apart from the three needed to suspend it, and you will be able to imitate the spinning cylinders which are such a great attraction at some fairgrounds. In these, the floor sinks when the cylinder is spinning fast enough leaving you clinging to the wall like a fly! If you take something out of your pocket and let go of it, it does not fall to the floor but clings to the wall too. Spin the can round at a good speed and small cardboard dolls, dropped into it like people at a fair, stick to the sides like flies. Centrifuges play a very important part in industry for separating dense liquids or solids from less dense liquids—for instance, for separating cream from milk.

Splitting the atom—in your own room

1 watch or clock with luminous fingers and figures
1 very strong magnifying glass or microscope

If there was one thing which the scientists of the previous century were sure about it was the performance, the unchangeability of the atoms and the elements. Iron was and remained iron, silver was and remained silver—there was no doubt about it at all. And the dream of the alchemists, to make gold from other metals, would never come to anything. These confident men of science suffered a great shock, about the turn of the century, when Madame Curie discovered radium, and when it appeared that this element changed of its own accord into other elements and finally lead. The nuclei of the atoms of radium threw out particles: alpha particles which are helium nuclei, and beta particles which are electrons, carriers of negative electricity. From these discoveries men were eventually able to release energy from atomic nuclei—atomic energy—and also to change one element into another, so realizing the dream of the alchemists. They even found that they were able to change other elements into gold, though the cost of this was far too great to make it commercially worth while.

It is possible that you have got a perfectly safe fragment of radioactive material in the house, a material from which the nuclei of the atoms eject particles spontaneously, changing meanwhile into other elements. Radioactive materials like this are to be found on the figures of luminous watches and clocks. It could well be a minute trace of radium bromide mixed with zinc sulphide. When an alpha particle ejected by a radium nucleus strikes a molecule of zinc sulphide, a tiny flash of light occurs. Because there are so many collisions between alpha particles and zinc sulphide you see all the flashes as a steady source of light.

But if you darken your room, get your eyes used to the dark and then, using a very strong magnifying glass such as a thread counter or the eyepiece of a microscope or telescope, look at the luminous spots, you may be able to observe the tiny flashes or scintillations. Every little flash that you see reveals that a helium nucleus has split off from an atomic nucleus and that the nucleus has changed into the nucleus of another element. You might even say that you have witnessed the splitting of an atom—though this would be rather an exaggeration because only a very minute fragment has been ejected.

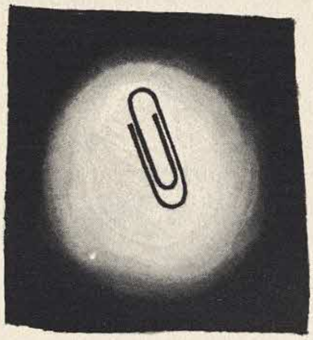
The individual scintillations can be observed better if you scrape a very small amount of the luminous paint from an old clock face and spread the powder out a bit. But for this you will need complete darkness and a very powerful lens.

Detecting radiation

1 shadow electroscope (see page 75)
1 clock or watch with luminous fingers or figures
Black paper
Photographic film

Radioactive materials send out alpha particles, beta particles and gamma rays. A Geiger-counter is usually used to demonstrate the existence of radioactivity and to measure its strength. The most important part of the instrument is an evacuated metal tube inside which is a well-insulated metal wire or tube carrying a high positive potential. The tube contains a small amount of a gas, for example, argon. Now, if alpha particles, beta particles or gamma rays (according to the radioactive source) pass through the tube, they remove electrons from any molecules of the gas which they may hit. This causes the gas molecules to acquire a positive charge and become 'ions'. The result is that a discharge of electricity takes place in the gas. The discharge can be rendered audible by means of a telephone or loudspeaker or visible by means of a neon lamp. The greater the number of crackles or light flashes, the stronger is the radiation. Geiger-counters like this are used, for instance, in prospecting for radioactive ores such as uranium.

There is a simpler though less reliable and sensitive method of demonstrating radiation and the presence of radioactivity: the electroscope. Charge a home-made electroscope (see page 75) by touching it with a rubbed comb so that the leaf stands out, and bring up to it a bit of radioactive material, e.g. the fingers or numbers of a luminous clock or watch. You will probably find that the electroscope is discharged much more rapidly than normally. This occurs, just as in the Geiger-counter, because owing to the radiation some molecules of the air acquire a positive charge; they are therefore attracted by the electroscope, and so discharge it. It works best if you remove the glass from the clock because alpha particles cannot pass very easily through glass.

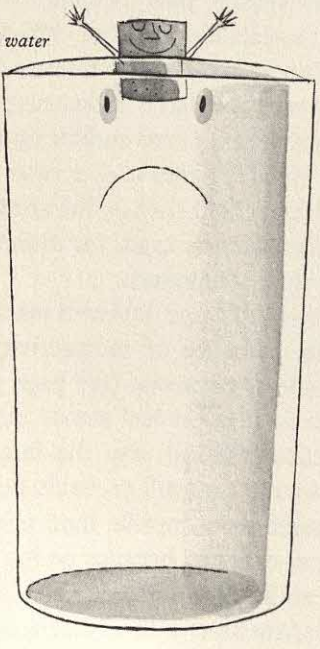


There is still another way of showing the radiation from radioactive materials: a piece of photographic film. In the dark wrap a piece of unexposed film between two pieces of black paper so that it is completely protected from the light. Now, in the light lay on top of the paper a paper clip and on top of that the clock with the luminous dial downwards. Leave it for at least a day and then develop the film. If the exposure has been long enough (it may need to be only a few hours but might require several days) you will get a shadow photograph of the paper clip just like an X-ray photograph, but made with the rays from your clock.

It was by the action of radiation on a photographic plate that radioactivity was first discovered—in 1896, by the French scientist Henri Becquerel. This led Madame Curie to her researches which resulted in such revolutionary discoveries. People who work in atomic plants or atomic laboratories wear a little piece of film inside a light-proof container. The film is developed after a fixed time and is replaced by a fresh piece. So it is possible to make sure that the people are not exposed too much to radiation. Radiation from radioactive materials can be very dangerous indeed, but you need have no fear of your watch or clock.

Make the cork obey you

1 glass
1 jug of water
1 cork



Fill a glass with water almost to the top and then challenge someone to float a cork on the water without letting it touch the side of the glass. You will have plenty of amusement at his attempts because you know for sure that he cannot succeed. When eventually he has had enough, your turn comes to show your scientific craft.

The solution is to pour more water very slowly into the glass until the centre of the surface is higher than the edges, so that you get a convex surface. The reason is that the floating cork on the convex surface—convex because of the surface tension—moves to the highest point where the tension is equal in all directions around it, and so it automatically reaches the centre and stays there.

You can copy photographs this way

Photographs and drawings in newspapers and magazines
Water
Turpentine
1 small piece of soap
Sheets of white paper
1 spoon

You probably know already that you can transfer printed pictures to a candle by rolling the picture round the candle, printed side inwards, and then holding it over a flame. You move the candle gently to and fro, turning it round. The printing ink and the candle get warm, with the result that the picture is transferred to the candle.

You can transfer newspaper and magazine pictures to white paper by using a mixture of water and turpentine. Make a mixture of four parts of water to one of turpentine. But, as you know, water and turpentine do not stay mixed. If you leave them to stand they separate out again with the turpentine on top. So a small piece of soap must be added to the mixture. Shake them well together until the soap has dissolved and your copying liquid is ready.

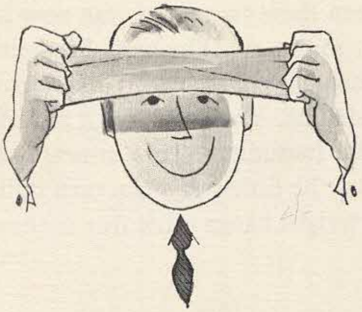
Now, if you want to copy newspaper photographs, lay the newspaper on the table with a couple more underneath it and moisten the photograph with a little of the mixture. Then lay a sheet of white paper on top. Now you will have to rub hard on top of the paper. This is best done with the back of a spoon. Sometimes it may be necessary to warm the liquid a little before using it.

Don't waste your time trying to increase your capital by copying banknotes by this method—it just is not good enough!

Rubber gets hot

1 strip of rubber

Rubber, which either comes from trees naturally or can be synthesized from oil or coal, is a most remarkable material. Its property of stretching to more than ten times its original length and returning to almost its previous size is surely unique. We make good use of this property almost every day. Think of motor tyres too. To the scientists rubber is a constant puzzle whose secrets have by no means all been solved. As an example, it is fascinating to realize that rubber, which is a solid, behaves in certain circumstances as though it were a gas. A gas is elastic, but in the opposite sense. While the force which a gas exerts increases when it is compressed, rubber exerts its greatest force when it is stretched. This comparison can be taken further: under compression a gas becomes hotter, whereas rubber heats up when it is stretched.



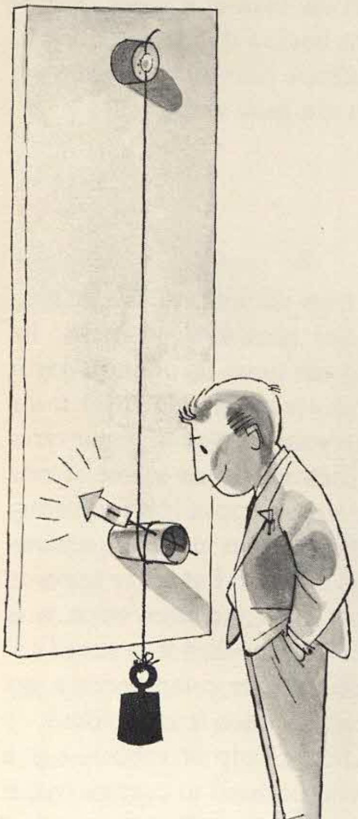
You can investigate this by holding a strip of rubber, e.g. a rubber band, unstretched against your forehead to confirm that it is cool. Now stretch it suddenly to about ten times its original length and hold it to your forehead again. It has quite definitely warmed up. Let it contract once more—it has cooled down again. When a gas is compressed, the work needed to compress it appears as heat in the gas; similarly, when rubber expands, the rubber is heated up by the work done in stretching it. In returning to its previous length the rubber loses heat, and so it feels cool against your skin.

A hygrometer

1 small plank or piece of hardboard
1 cork
Gum or glue
1 long hair
1 small weight
1 drinking straw
Warm water
1 piece of stiff paper
1 pair of scissors
1 pen or pencil
1 needle
1 pin
Soap and soda

A hygrometer enables you to measure the dampness, or humidity, of the atmosphere. The way in which this one works depends on the fact that the length of a hair varies with changes in the dampness of the air. You will need a hair between 12 and 15 in. long. Wash it very carefully in warm water with soap and soda to remove all the natural grease. Rinse it well and let it dry. You can dry it by leaving it to lie on a sheet of clean blotting or kitchen paper.

Glue or screw a cork on the board or strip of hardboard and stick one end of the hair to the cork with a drop of quick-drying cement. At the spot shown on the drawing drive a needle into the board and slide a piece of drinking straw over it. (The drawing, as you can see, is exaggerated to make the principle clear.) This piece of straw must be a little longer than the needle so that you can push a pin through it to form the support for a light paper pointer. Tie the other end of the hair to a small weight such as a ring or small nut, wind the hair once round the straw and your hygrometer is almost ready. The only remaining job is to calibrate the scale. Hold your hygrometer over a small pan of boiling water which you have covered with a damp cloth. After a little while the pointer takes up a certain position which it maintains. Mark this position 100. At the position which the pointer takes up when you hold your hygrometer over a stove or radiator, or out of doors on a clear, bright, cloudless day, put 0. The arc of the circle between these two points can now be divided up with the figures 10, 20, 30, 40, etc. The best alternative method of calibration is to compare the positions of your hygrometer with those of a factory-made one. You can hang it up and then you will be able to read the humidity of the atmosphere whenever you wish. Make sure that the little straw can turn quite freely on the needle and that the weight hangs quite free without touching anything.

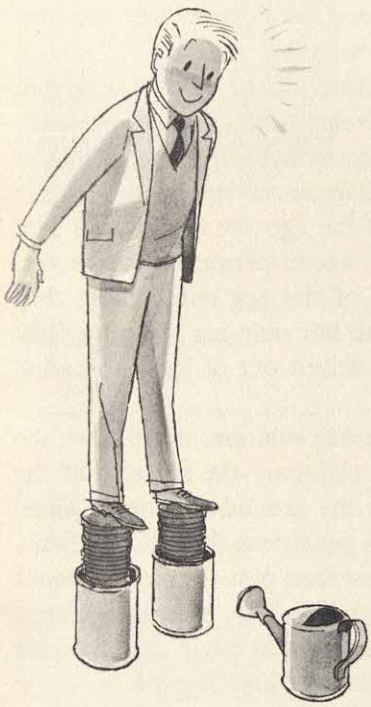


Capillarity is irresistible

2 empty tins without lids
Cardboard
1 pair of scissors
Water
Soapless detergent

If you stand a narrow tube upright in a cup of water you will see that water rises up the tube, higher than the surface of the water in the cup. Now as a general rule, if you have two or more vessels that are connected by a tube, the surfaces of any liquid that is poured in will always lie horizontal, always have the same level. But this does not hold if the vessels are very thin, like capillary tubes. In these, because of the attraction between the molecules of the glass and those of the liquid, the latter is pulled upwards. This is why the water rises.

In our daily lives we make extensive use of capillarity in countless ways. The sucking action of blotting paper, cotton wool, tea cloths and floor cloths, the wicks of candles and oil lamps, is due to capillarity, and so is the ability of trees and plants to take up water from the ground. From very ancient times man has made use of it in many practical applications. The Egyptians used to drive wooden wedges into blocks of stone, then wet the wedges with water and so cause them to swell up and split the stone. When the ropes which were used for lifting heavy stone blocks stretched too much, they were wetted so that they shrank and raised the tons of stone. The enormous force which was exerted in this way can be demonstrated very simply.



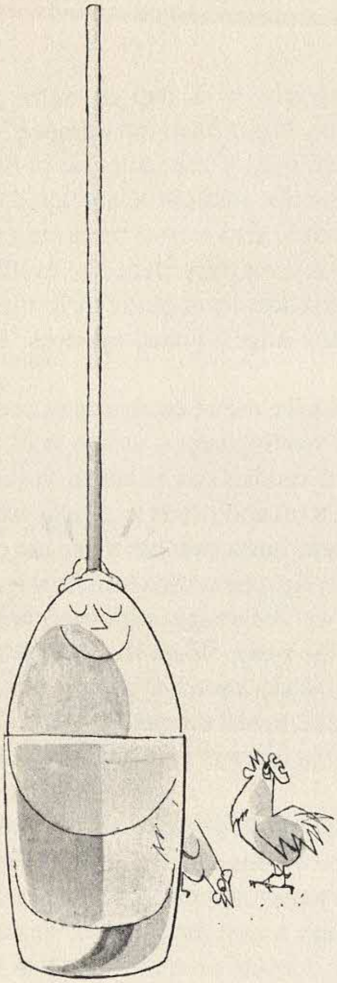
From ordinary porous (not waterproofed) cardboard cut a whole lot of squares and stack them into two tins, right to the top. Stand on them and get someone to pour water, containing a little soapless detergent, into the tins. By capillary action the pores in the cardboard absorb the water and swell, exerting so much force that you are lifted quite a few inches—a very convincing demonstration of the force of capillarity!

The marvel of osmosis

1 drinking glass
1 small, sharp knife
Water
1 fresh egg
1 drinking straw or glass tube
Sealing wax
1 pin

Osmosis is a mutual exchange between two different, miscible liquids through a semi-permeable membrane (or skin). It plays an extremely important role in Nature—yes, without osmosis life would be impossible! Osmosis is the process by which the nutritious part of our food passes through the walls of the intestine into the blood stream. The same process enables the body cells to take in these materials.

The marvel of osmosis can be demonstrated in a very spectacular way with a fresh egg. Use your nail or a very sharp knife to remove a small chip from one end of the egg without damaging the membrane underneath. At the other end of the egg prick a small hole with a pin and gently enlarge it until it will take a drinking straw, or, better, a glass tube about the same size. Push the tube about half an inch into the hole. Light one end of a stick of sealing wax, let it burn for a few moments, blow the flame out and let drops of wax fall on the egg round the tube. Keep on doing this until you have a completely air- and water-tight seal between the egg and the tube. Now stand the egg, tube upwards, in a glass three-quarters full of water. You will have to wait a while, but eventually you will see the contents of the egg slowly rising up the tube. After some hours or even days the tube overflows and little by little the contents of the egg pass right through the tube.



How does this happen? The contents of the egg are separated from the water by the membrane. Even so, the water penetrates it. In the membrane there are minute pores through which molecules of water and of many dissolved substances can pass. But the molecules of the white and yolk of the egg are too large to pass through it. This is what we mean by a semi-permeable membrane. So the water pushes the contents of the egg out because they cannot pass through the membrane but only up the tube. The result is that the egg is gradually driven out of its shell and is replaced by water!

This is osmosis, in which the weaker solution, in this case the water, moves towards the stronger solution—the contents of the egg. In the same way water from the ground containing small quantities of dissolved mineral salts penetrates the cells of plants. This is how the valuable parts of our food pass through the walls of the intestine into the blood stream. The body cells in their turn receive the solutions from the blood while other materials are removed, but the protoplasm of the cells cannot escape.

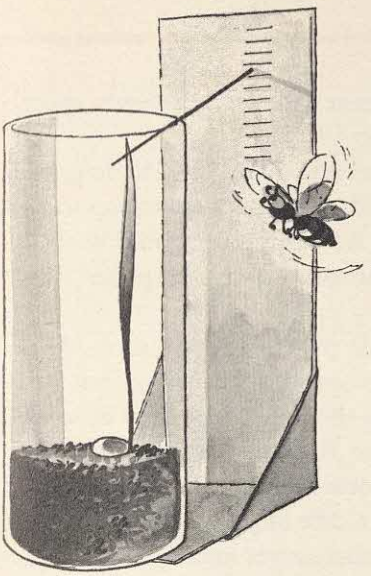
Watch it grow

1 small glass or plastic tube about 3 × 1 in.
Peat or bulb fibre
1 fine stiff broom bristle about 4 in. long
A few maize or sweet corn seeds
1 strip of postcard
1 small block of wood

It was so quiet that you could hear the grass grow! Have you ever heard somebody say that? Have you ever been out in the country on one of those lovely quiet days when all is still? Perhaps you have even heard the grass grow. On the other hand it is more than likely that you have seen one of those films which shows, by time-lapse photography, a plant growing or a flower opening. What a fascinating sight to watch, isn't it?

A very simple little experiment will enable you to watch a plant growing, in silence, but not as rapidly as in a time-lapse film.

Soak some maize or sweet-corn seeds overnight. Next day



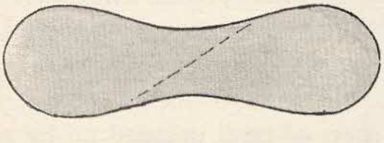
prepare a small tube, glass or plastic, by putting about half an inch of damp peat, bulb fibre or good soil in the bottom. Then put one of the soaked seeds on top of the peat. It would be as well to prepare one or two more just in case one of the seeds fails to germinate. Keep the little tube in a warm place for a few days, making sure to keep the peat moist. When the seed germinates, a single shoot grows upwards and after a time it nearly reaches the top of the tube. Now take the bristle, or similar light, stiff fibre, push one end of it through the tip of the leaflet and let the bristle rest on the side of the tube (see the drawing). This will make a simple little pointer. Keep the whole thing warm, but not hot. A small scale mounted behind the bristle will help you to watch its movements more easily. The long end of the bristle magnifies the movements of the tip of the leaflet.

Which way does the long end of the bristle move?

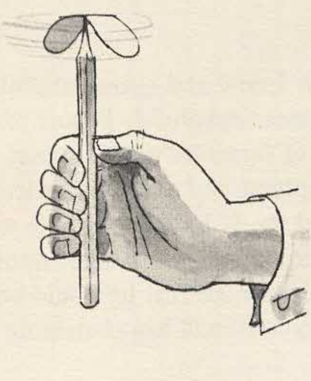
A turbine which runs on the heat from your hand

1 piece of very thin paper
1 pair of scissors
1 pencil
1 razor blade or very sharp penknife

We are going to make an air-driven turbine which is so sensitive that it will work by the heat from your hand. To make it use some very thin paper, for example carbon paper, and cut from it a propeller of the shape shown in the drawing. Fold it along the dotted line to an angle of about 90°—a carefully rounded crease. The fold must not be sharp, for then the experiment will not work. Lay the propeller lightly on the point of a pencil held upright. The point must be very very slightly rounded by one or two gentle oblique strokes on a piece of paper. If the propeller balances well on the point of the pencil and none of it touches the pencil, it begins to revolve. Is it because of your breath? Hold your breath then! It still goes on turning. Stand it in the sugar basin. It stops turning. Pick it up, it begins to turn again because the heat of your hand makes the air rise.



This air turbine is useless above a stove or radiator because it is too sensitive, but above your hand or wherever there are gently rising currents of warm air it works excellently. At the point where the propeller rests on the pencil point make a tiny dent by pressing it very gently, but be careful that you do not make a hole in it. That self-lubricating layer of graphite reduces the friction sufficiently to enable the air turbine to react to the slightest current of air. Shut the windows of your room and try to find out where the strongest draughts are.



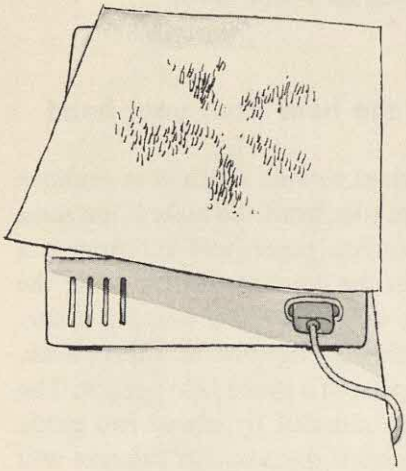
Marvels with magnets

1 electric gramophone
1 or more magnets
Iron filings
1 smooth sheet of paper

One of the most beautiful and most fascinating science experiments that I know is the following:

Lay one or more magnets on the turntable of an electric gramophone. If the gramophone has a lid, raise the magnets up so that they are as near as possible to the lid when it is down. On the lid lay a sheet of smooth paper, e.g. the sort of shiny 'art paper' which is sometimes used for calendars.

Sprinkle some iron filings on the paper. You can probably get some filings quite easily from a shop that cuts keys (not brass ones!), from a blacksmith or from the metalwork shop at school. Sprinkle the filings very lightly so that they are evenly spread. Now hold the paper steady with one hand so that it cannot turn round, and tap on the lid with the middle finger of your other hand. You will see the filings arranging themselves into the most attractive patterns in a very mysterious manner; a visible demonstration of the lines of force within the magnetic field.



But it is even more fascinating when you switch on the motor of the gramophone, for then the iron filings start to move round the paper in circles. It is just like small ants or other tiny insects, moving in mighty armies. Look through a magnifying glass. To your amazement you will see the filings clinging together, one on top of the other and in groups. They look like a forest of little fir trees. And these trees are not sliding along as you would expect, but move head over heels over the paper.

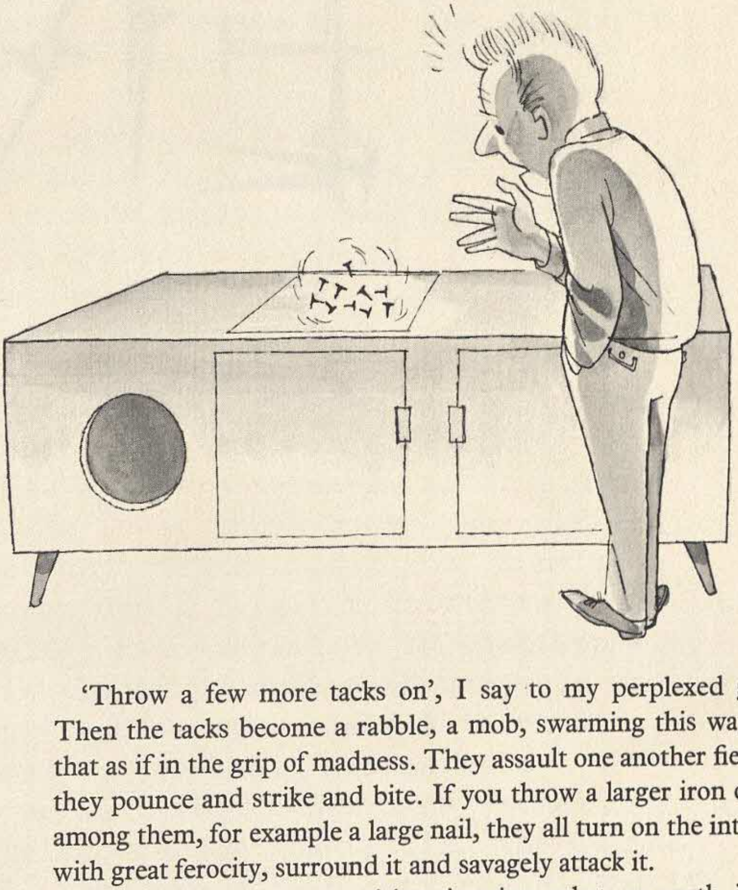
Don't let the gramophone turn at less than 33 r.p.m. The experiment is most successful with three or four of the very powerful circular ring-shaped magnets such as are found round the tube in television sets. If the gramophone has no lid, or the lid is too far above the turn-table, lay a stiff sheet of card, propped up by a couple of boxes or blocks of wood, above the turntable.

Tin-tacks bewitched

1 gramophone
1 or more strong magnets
Some nails with large heads

Of all the experiments with which I now and again entertain my friends this one seems to me the most delightful. I must tell you that in our house we have a piece of furniture which houses in an unobtrusive way a radio, a gramophone and a tape-recorder. The top of it is a lid which can be lifted up. If I spot a possible willing victim among our guests I tell him that I have bought some tin-tacks which are so strange in their behaviour that he would be very worried about them. And then I show a small bag containing some apparently ordinary large headed tin-tacks. The visitor usually says that he cannot see anything strange about them. 'That's what you think!' I say. 'Take a few and throw them down here, then you'll see if they are ordinary tacks or not.'

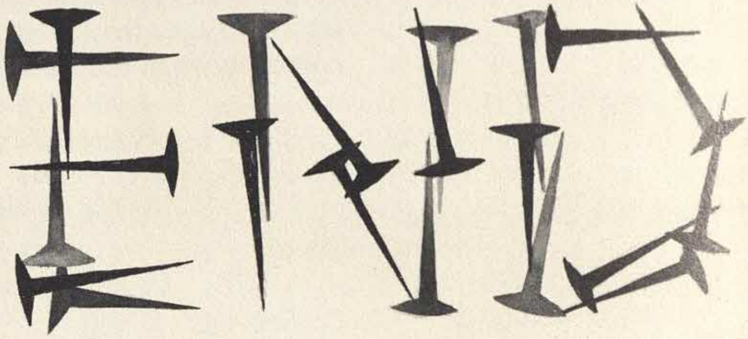
Meanwhile, I have seated the visitor near the 'cabinet'. Slightly incredulous he picks up a few nails, lets them drop . . . and then has the surprise of his life. For the instant that the tacks fall on the top of the cabinet they run away, head over heels, some in fantastic zigzags, crawling round and round just as though they had been bewitched into live creatures, creeping insects, iron ants. . . . Yes, they carry on just like living things; two or three of the nails play tag, and when one catches the other they scrap and wrestle, until one suddenly takes to his heels and gets far out of reach of the others. Then the exciting chase begins all over again, and if you trap a couple underneath an inverted glass there follows a long-drawn-out, tough struggle inside the walls of the glass prison.



'Throw a few more tacks on', I say to my perplexed guest. Then the tacks become a rabble, a mob, swarming this way and that as if in the grip of madness. They assault one another fiercely, they pounce and strike and bite. If you throw a larger iron object among them, for example a large nail, they all turn on the intruder with great ferocity, surround it and savagely attack it.

Deeply impressed, my visitor inquires what on earth is the matter with the tin-tacks. Then I ask him to take them all away, but this isn't too simple because they are very elusive. Then I lift the lid. The spell has gone, for the revolving turntable is revealed —a turntable on which one or two magnets are lying, attracting the tacks right through the lid and magnetizing them! It is this magnetism that makes the tacks attract and repel one another. Here is the secret of the warlike games, the wrestling and the biting carried on by the bewitched tacks, drunk with magnetism. . . .

On the turntable of a gramophone lay a few magnets, sprinkle a few tacks on the lid or on a smooth sheet of cardboard laid above the turntable and you, in your own home, can have a demonstration like that mass-hysteria of the big-headed tin-tacks. And when you have had enough of it, a click of the switch brings the hysteria quite completely to an



A letter from the Author

Dear Reader,

As its title indicates, this book of experiments has two predecessors. All three books have been written with one aim in mind - to arouse your interest in science and to give you a basic knowledge of it.

Life becomes more interesting if you try to understand the things around you, from the most minute plant or insect to the mightiest stars which are millions of times larger than our earth; from the tiniest transistor radios to the gigantic radio telescope; from the miniature engines of model planes to the towering rockets that will carry man to the moon. And the key to understanding all these things is - science.

This book and its predecessors enable you to discover some of the basic laws of science for yourself. There is no better or more enjoyable way of studying science than learning through experience. Indeed, you may find it such fun that you decide to make science your hobby.

It's a wonderful thing to have such a hobby - something of your own choice that you can develop by your own talent, enterprise and perseverance. After you have done the experiments in these three books, why not read more widely on these subjects? Consider your home as your laboratory (though don't forget that others live there besides yourself!) and specialize in what appeals to you most. There is plenty of choice of subjects to read about and things to do: experiments with physics, chemistry, biology and meteorology; microscopic research; constructing electronic apparatus, model planes or a mirror-telescope for penetrating the depths of the universe. All these are within your reach! And if you co-operate with other young people in your school or neighbourhood to form 'Science Clubs', even more ambitious projects can be undertaken. Many such clubs have enlisted the help of local industries, have run 'science fairs' and done all sorts of things that would be impossible for an individual science enthusiast.

Science as a hobby may be only the prelude to science as a career. The world needs scientists. It is the man in the white coat who will plan and construct the world of tomorrow, helping to liberate millions of men, women and children from poverty, hunger and disease. So don't listen if anyone is inclined to make fun of your keenness on science. Remember that the thrill of 'finding out' has already led men to epoch-making discoveries. A painter named Morse, who was greatly interested in electromagnetism, performed experiments that led to the invention of the telegraph. A teacher of the deaf-and-dumb, Bell, invented the telephone. A teenager with a passion for physics - Marconi - built the first radio. The Wright brothers, makers of bicycles, whose hobby was the study of flight, constructed the first powered aeroplane that actually flew. Well, what enormous influence on our world these inventions have had!

So - pursue your interest in science, regardless of what others may say. Your hobby is bound to give you enjoyment, and some day it may enable you to benefit mankind.

Leonard de Vries

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The book of experiments

'This has been written in a light-hearted vein. In fact the drawings are what many a cartoonist would give his right arm to do. In all, there are a hundred and forty-nine different experiments, and each has been chosen to astonish and to arouse the liveliest curiosity in the onlooker. Some of them will be remembered as old parlour games. Every so often the author pauses to explain in delightfully simple terms the scientific theories that lie behind his experiments. The principles brought to light by these experiments have been drawn from as wide a field as possible in elementary physics and chemistry.'—*New Scientist*

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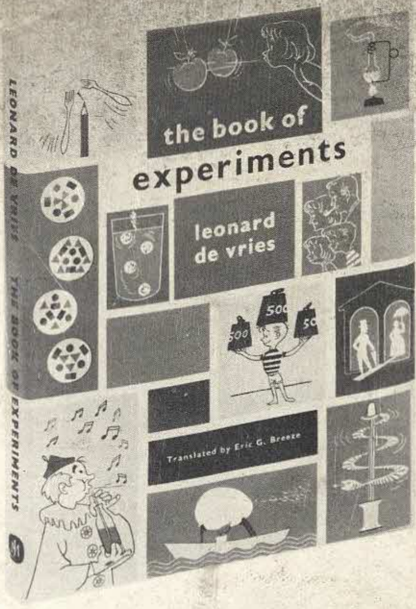
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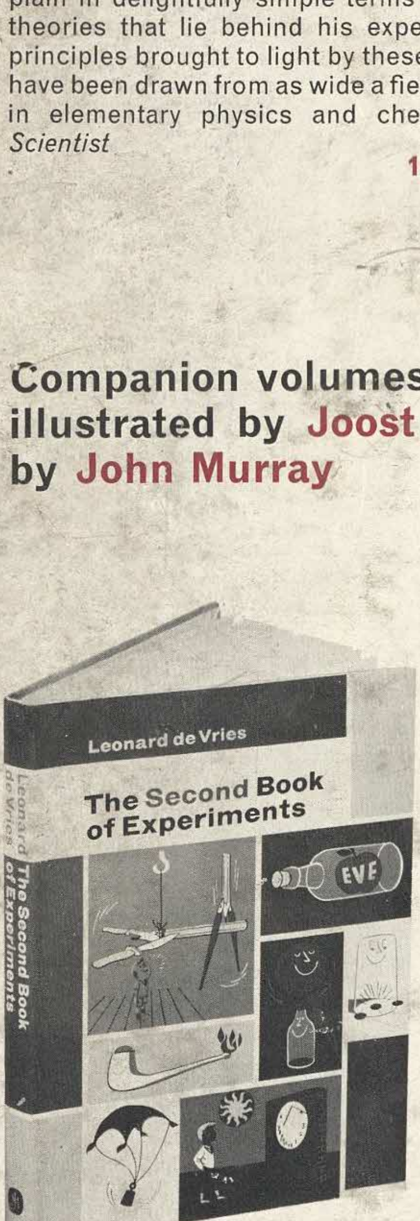
Leonard de Vries
The Second Book of Experiments
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The second book of experiments

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